BT-1721 Superpressure Balloons for Horizontal Soundings of the Atmosphere

Access Number
BT-1721

Title
Superpressure Balloons for Horizontal Soundings of the Atmosphere

Author
Vincent E. Lally

Responsible Organization
National Center for Atmospheric Research

Funding Organization

Date
Jun 1967

Report Number
NCAR-TN-28

Repository Number

Contract Number

Description
Technical Report, 174 p, 4 refs

Notes
A revised and updated version is dated Oct 1971.

Key Words
Superpressure, long duration, design, theory, stability, instrumentation, thermal effects,flight tests

Content
This report became the definitive treatise of its time for the technology of superpressure balloons. It may still be considered a landmark document and is timeless in its coverage of the technology. Topics

covered include balloon types and designs, superpressure theory, potential balloon lifetime, effects of solar and other infrared sources on balloon performance, balloon stability, and failure causes. Diagnostic sensors, tracking technologies, balloon integrity testing, and flight test results are also covered.

Available From
WFF/BTL

NCAR-TN-28

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VINCENT E. LALLY

June 1967

(NCAR-TN-28) SUPERPRESSURE BALLOONS FOR HORIZONTAL SOUNDINGS OF THE ATMOSPHERE (National Center for Atmospheric Research) 177 p

N87-70103

29996

Unclas

00/47 42922

NCAR Technical Notes

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
Boulder, Colorado

NCAR-TN-28

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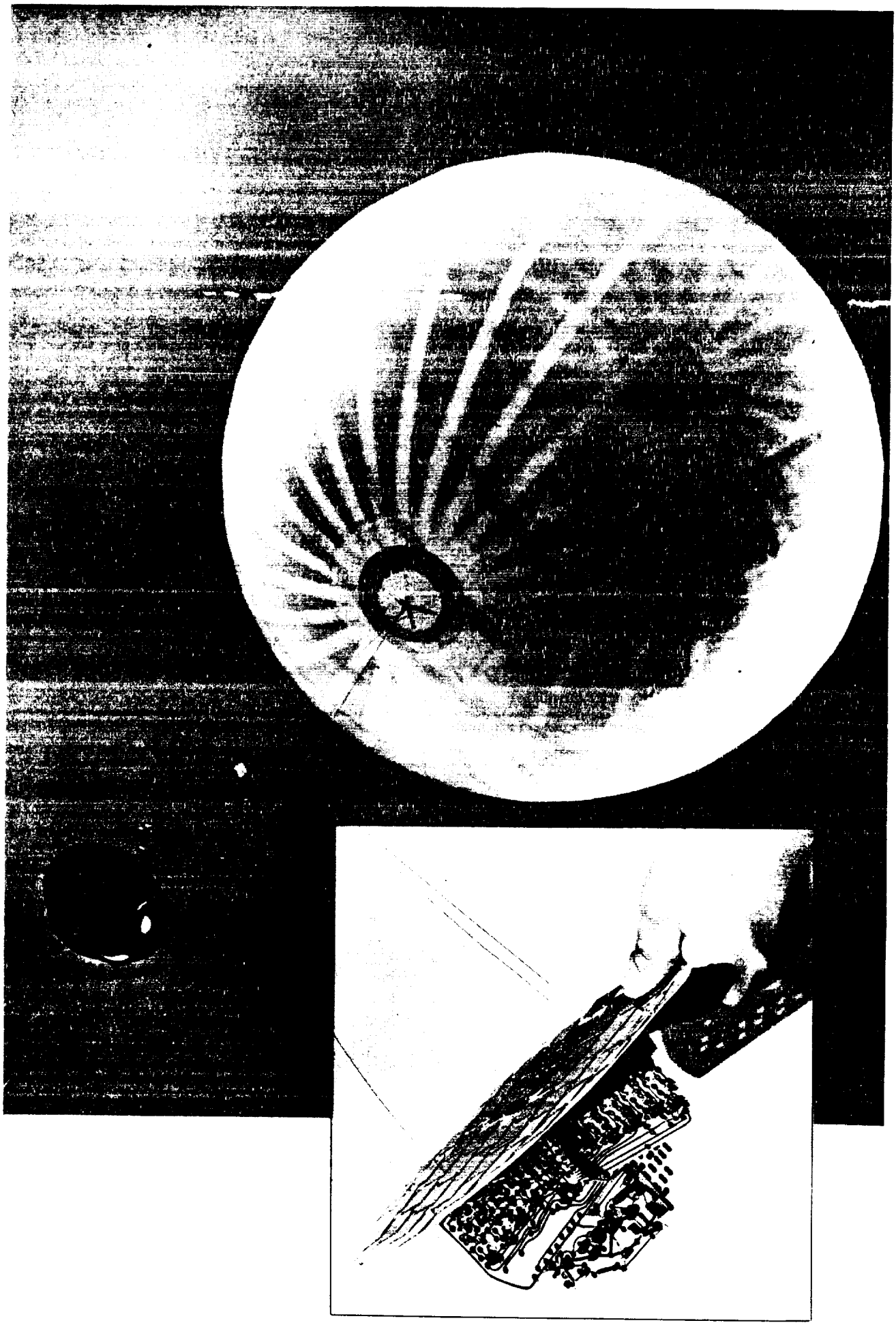

FOREWORD

These notes are designed to provide under one cover the status of superpressure balloon technology. For a number of years the promise of long duration flight with superpressure balloons has been taken on faith alone. Between March, 1966, and March, 1967, 85 flights were made in the southern hemisphere under the auspices of the New Zealand Meteorological Service, the Environmental Science Services Administration, and the National Science Foundation. The flight program was conducted by the National Center for Atmospheric Research.

This technical note is a collection of previous reports and articles which have been updated on the basis of the Southern Hemisphere GHOST (Global HOrizontal Sounding Technique) flight program.

The establishment of the GHOST flight program in the southern hemisphere was a major achievement in international cooperation. We are grateful for the assistance of D. A. Davies, Secretary-General of the World Meteorological Organization; Dr. John F. Gabites, Director of the New Zealand Meteorological Service; and Dr. Robert F. White of ESSA for their efforts in obtaining approval and cooperation throughout the southern hemisphere. The cooperation of the volunteer tracking stations has been of inestimable value during the first year of GHOST flights. The assistance of these stations is gratefully asknowledged: Luanda, Angola; McMurdo Station, Antarctica; Buenos Aires, Argentina; Melbourne, Australia; Rio de Janeiro, Brazil; Papeete, French Polynesia; Plaisance, Mauritius; Pretoria, South Africa; and Broken Hill, Zambia.

I am personally indebted to Ernest W. Lichfield and Robert W. Frykman who developed the remarkable electronics systems used on all GHOST flights, to Neil Carlson who designed and fabricated much of the

electronics, to Marcel Verstraete who supervised balloon testing and launching during much of the program, and to Jane Von Letkemann who patiently assembled these notes.

The analysis of trajectory data for the 85 GHOST flights is presently under way under the supervision of Samuel B. Solot. Complete trajectories will be published at a later date.

Vincent E. Lally

June 1967

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I. THE SUPERPRESSURE BALLOON -- HOW IT FLIES

Three types of balloons are in common use for scientific research or meteorological observations.

The rubber or neoprene balloon is used for vertical soundings either as a pilot balloon or as a radiosonde-carrying balloon. It is inflated with a lifting gas (hydrogen, helium, ammonia, or methane) and stretches as it ascends. When the material has stretched to three to six times the unstressed length (the balloon would then be thirty to two hundred times its original volume) the film ruptures.

The zero-pressure plastic balloon (most commonly polyethylene) is used to carry scientific instruments to a predetermined density level. The plastic balloon is only partially filled with gas on the ground. As the balloon ascends, the expanding gas fills the envelope. This type of balloon has some form of open appendix or duct to release the excess gas which provides the free lift for ascent. When the excess gas is forced out, the balloon floats at its constant-density altitude until there is a change in the radiation environment. At sunset the gas cools, the volume decreases, and the balloon descends to the ground unless ballast is released.

The superpressure balloon is a non-extensible balloon which is sealed to prevent gas release. It has converted the free-lift gas into superpressure by the time floating level is reached. Variations in the radiation environment produce changes in the superpressure, but not in the balloon volume. As long as the balloon is superpressured, it will continue to float at a constant-density level.

The superpressure balloons which have been fabricated to date utilize plastic materials which do stretch as the superpressure changes, producing small changes in balloon volume. In Section VI the variation

in float altitude because of changes in balloon volume is discussed. As gas diffuses through the balloon film or escapes through pin-hole leaks, the mass of the system changes. The effect of these changes on stability is also discussed in Section VI.

Any change in total mass of the balloon system will cause a variation in altitude. The system mass may increase because of the adhesion of liquid water to the balloon film; however, simple surface treatments can reduce the amount of water contained on the balloon to a negligible amount. The accretion of ice in the form of frost, ice crystals or frozen droplets resulting from impact of the balloon with supercooled water is a much more serious problem. No reliable technique has been developed for removing ice from the balloon film. If the balloon accumulates an amount of ice which exceeds the initial free lift of the system, the balloon will descend. A complete description of present knowledge of the modes of balloon failure and methods of minimizing icing is given in Section VIII.

II. BALLOON SHAPES AND STRESSES

A balloon can be manufactured in any desired shape. When the balloon is superpressured, the stress distribution will vary over the surface, with the highest stresses in areas of maximum radii of curvature. Only the sphere provides uniform stress distribution over the entire surface. Intuitively, it would appear that the sphere is the most efficient shape for providing the largest enclosed volume at a given maximum stress and a given mass of material. However, constructional difficulties arise which can offset much of the geometric efficiency of the sphere. In addition, the application may be one where factors other than efficiency are of prime importance. For example, the cylinder is a simple structure which is less affected by vertical currents at low altitudes; the tetroon provides a compromise between ease of construction and design efficiency which makes it suitable for low-cost flight programs where maximum performance is not required.

A. THE PROLATE SPHEROID

The majority of shapes which are useful in the design of superpressure balloons can be considered as prolate spheroids. The sphere can be considered as a prolate spheroid in which the major and minor radii are equal. The cylinder can be considered as a prolate spheroid for which the major radius is very much larger than the minor radius. The volume of a prolate spheroid is:

$$V = \frac{4}{3} \pi a b^2$$

The surface area of the spheroid is:

$$A = 2\pi \left[b^2 + \frac{ab}{\epsilon} \arcsin \epsilon \right]$$

where a and b are the major and minor radii and $\epsilon^2 = 1 - \left(\frac{b}{a}\right)^2$. The maximum meridional stress on a prolate spheroid is:

$$S_m = \frac{286\ b\ \Delta P}{t}$$

where

S_m = meridional stress (psi)

ΔP = superpressure (mb)

t = film thickness (mils)

The maximum circumferential stress on a prolate spheroid is:

$$S_c = \frac{572\ b}{t}\left(1 - \frac{b^2}{2a^2}\right)\Delta P$$

A prolate spheroid with a fineness ratio of 3 $\left(\frac{a}{b} = 3\right)$ appears to be an ideal vehicle for maintaining vertical stability at low altitudes. In Section VI the stability of such a balloon is compared with that of the sphere.

B. THE CYLINDER

The cylinder is an inefficient shape for a superpressure balloon, but it is simple to manufacture and provides a low drag relative to an equivalent sphere. It has application to low-altitude flight with light payloads. The circumferential stress on a long cylinder is:

$$S_c = \frac{572\ r\ \Delta P}{t}$$

where r = radius (m), and other symbols are as above. The meridional stress on a long cylinder is:

$$S_m = \frac{286\ r\ \Delta P}{t}$$

C. THE SPHERE

A sphere manufactured of homogeneous film without seals will have a uniform stress distribution over the entire surface which can be expressed as:

$$S = \frac{286\ r\ \Delta P}{t}$$

Spherical balloons have always been fabricated from a series of flat gores. Usually 18 to 24 gores are used to approximate a sphere. The tapes which seal the gores provide additional meridional strength. The stress around the balloon equator can be approximated by the formula for homogeneous material. The stress from pole to pole will be approximately two-thirds the equatorial stress.

D. THE TETROON

The tetroon, or tetrahedron, is made from a cylinder whose circumference is equal to 2.31 times the cylinder length. The ends are sealed as pillows with the seams orthogonal to each other. A complete description of the tetroon is given in Ref. 1. The basic advantage of the tetroon is manufacturing simplicity. Stresses on the triangular faces are much higher than the stresses on a sphere. The tetroon is not considered further in this report.

III. FREE LIFT AND SUPERTEMPERATURE STRESSES

A. SUPERPRESSURE DUE TO FREE LIFT

A superpressure balloon is normally launched as a sealed container. It can be lifted to the desired altitude by a tow balloon or it can be inflated with an excess of lifting gas which is valved upon reaching altitude. This second alternate is undesirable for long duration flights since it adds a complicated device which may cause leakage. Fortunately, the free lift used to carry superpressure balloons aloft without assistance (10 to 20%) provides a satisfactory ascent rate. Figure 1 illustrates the variation of ascent rate with free lift for spherical balloons. This free lift becomes the superpressure at floating altitude (the "bank" of excess gas which is drawn upon to sustain flight for extended periods).

Equations 1 through 10 (Appendix A) provide the derivation of superpressure due to free lift. The superpressure due to free lift equals the percentage free lift times the atmospheric pressure at float altitude, if we define percentage free lift as the ratio of free lift to the gross system mass including the mass of the lifting gas. Table 1 relates percentage superpressure to percentage free lift for the most common definition in which the mass of the gas is not included in the system mass.

B. SUPERPRESSURE DUE TO SUPERTEMPERATURE

Equations 11 through 14 derive the relationship of superpressure to supertemperature. We can made a very good approximation that a 5% supertemperature produces a superpressure of 5%. It should be clearly noted that changes in air temperature do not directly affect the superpressure. The balloon floats along a constant-density surface. If the

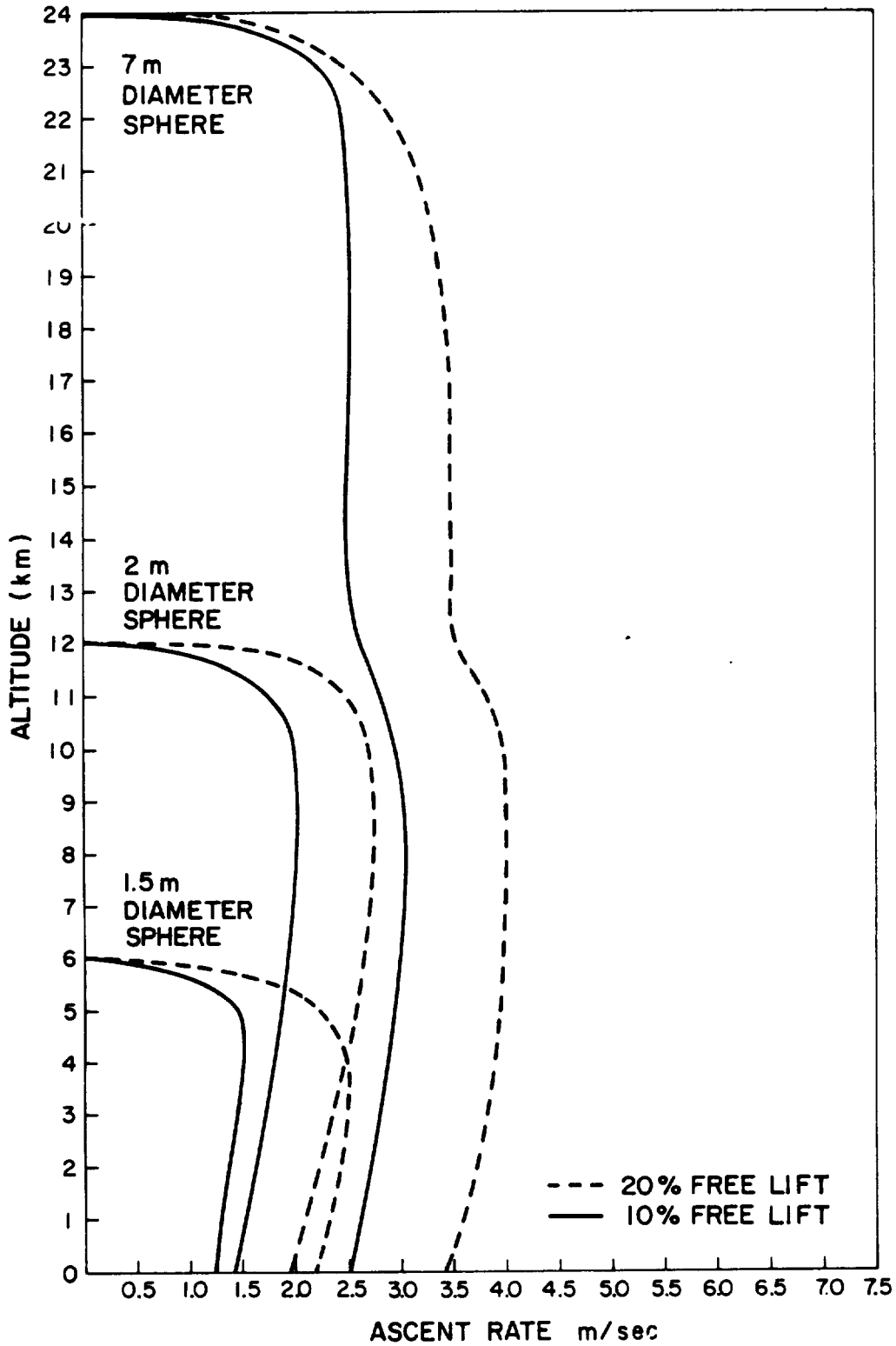


Fig. 1 Ascent rate of superpressure balloons for 10 and 20% free lift

Table 1

SUPERPRESSURE DUE TO FREE LIFT [a]

Free lift ÷ Balloon mass + payload mass	$\frac{\text{Superpressure}}{\text{Atmospheric pressure}} = \frac{\text{Free lift}}{\text{Balloon mass + payload mass + gas mass}}$	
	Helium	Hydrogen
0.02	0.018	0.019
0.04	0.035	0.038
0.06	0.052	0.056
0.08	0.070	0.075
0.10	0.087	0.093
0.12	0.104	0.111
0.14	0.123	0.130
0.16	0.138	0.148
0.18	0.154	0.167
0.20	0.172	0.185
0.25	0.214	0.230
0.30	0.251	0.276
0.40	0.336	0.366
0.50	0.414	0.455
0.60	0.493	0.540
0.70	0.569	0.627
0.80	0.642	0.715
0.90	0.714	0.798
1.00	0.784	0.876
1.15	0.885	1.000
1.32	1.000	

[a] If free lift is defined as the ratio of free lift to <u>total</u> system mass, the free lift superpressure as a fraction of atmospheric pressure is equal to the free lift ratio.

air temperature decreases, the balloon floats at a lower pressure -- but the superpressure does not change.

There are only two factors that produce superpressure -- the initial free lift and the difference between lifting gas temperature and air temperature, which we call supertemperature. Supertemperature is an awkward expression (especially since it is so often negative), but is it used in place of the more common but incorrect expression, superheat.

The supertemperature varies not only from night to day, but also during the day as the radiation environment changes. The extremes for polyester (polyethylene terephthalate) balloons measured in flights to date are over the range -5% (tropics, 500 mb, nighttime) to +10% (polar, 200 mb, daytime). The flight data are limited and actual extremes may be much larger. The sunset effect on these balloons has been measured at 3 to 5%. A more detailed analysis of supertemperature variations is included in Section VI.

C. STRESSES PRODUCED BY SUPERPRESSURE

The expression for the stress produced by free-lift superpressure and the supertemperature-produced superpressure is given by Eq. 17. In practical units this can be stated as:

$$S_{sphere} = \frac{286\ r\ P}{t}\left[f + (1 + f)\frac{\Delta T}{T}\right]$$

where

S = stress (psi)

r = radius (m)

P = atmospheric pressure

t = film thickness (mils)

f = free lift ratio

$\frac{\Delta T}{T}$ = fractional superheat

IV. BALLOON LIFE

A. DIFFUSION

For the purpose of this report, we shall distinguish between two methods of gas loss from a superpressure balloon: diffusion and leakage. We define diffusion as the gas loss through the walls of a balloon that is without defect in material or assembly.

We define leakage as gas loss through defects in the balloon, whether these be pinholes, defective seals, or abrasions which permit a larger gas loss than is realized with film areas without imperfection.

When a plastic film contains a gas, the gas dissolves in the film and diffuses to the outside. The rate at which the gas passes through the barrier varies directly as the permeability of the film to the gas, δ, and the partial pressure, p, of the gas across the film, and inversely as the film thickness, t:

$$\text{Rate of loss} = \frac{\delta pA}{t}$$

For a balloon, the percentage loss of gas per day can be obtained by dividing the rate of loss by balloon volume:

$$\text{Per cent volume loss per day} = \frac{100\delta pA}{tV}$$

For a <u>spherical</u> balloon, the percentage loss of gas per day is:

$$\text{Sphere per cent volume loss per day} = \frac{300\delta p}{rt}$$

where

δ = film permeability (m^3/m^2, mil/mb-day)

p = partial pressure of contained gas (mb)

r = balloon radius (m)

t = thickness of film (mils)

For a cylindrical balloon, the equation becomes:

$$\text{Cylinder per cent volume loss per day} = \frac{200\delta p}{rt}$$

The permeability of plastic films is a marked function of temperature. Permeability at low atmospheric temperatures (200°K) may be less than 1% of the value at high temperatures (300°K).

Table 2 provides permeability data for a number of gases and films at 25°C. Table 3 gives specific data on the permeability of the polyester Mylar to helium at various temperatures. The values are derived from a number of sources. Since the permeability of Mylar to helium varies with the percent crystalinity of the Mylar film, the data available are not consistent. The data derived by Lally, Mellor, and Verstraete in extensive tests with inflated balloons indicate lower values than given by other sources, with the exception of the General Mills, Inc. tests made in 1960. These values are used in Table 3, since the combination of stressed film, bilamination, and taped areas appears to provide a lower overall diffusion than would be indicated from the other test results.

Figure 2 shows expected life of balloons at several altitudes using permeability values from Table 3 and an assumption of 10% gas loss to failure.

Circled points on the 500-mb and 200-mb curves are the designs which have been used in the initial GHOST test flights in the southern hemisphere. Life expectancies for balloons without defect are 180 days for a 2.5-mil balloon at 500 mb and 3 years for a 1.5-mil balloon at 200 mb.

B. LEAKAGE

Diffusion of gas through a plastic film is a function of the partial pressure of the gas contained within the film. Leakage is a function of

Table 2

PERMEABILITY (δ) OF FILMS TO GASES AT 25°C

Film	Gas [a]			
	He	H_2	O_2	N_2
Saran	7.5×10^{-7} (0.03)	2.5×10^{-7} (0.01)	1.2×10^{-8} (0.0005)	2.5×10^{-9} (0.0001)
Mylar	22×10^{-7} (0.088)	15×10^{-7} (0.06)	7.5×10^{-8} (0.003)	1.2×10^{-8} (0.0005)
Polyethylene	185×10^{-7} (0.74)	220×10^{-7} (0.86)	140×10^{-7} (0.55)	50×10^{-7} (0.20)

[a] First-line entries are δ in NCAR units; bracketed entries are in "trade" units. To convert from trade units to NCAR units, multiply by 2.5×10^{-5}.

NCAR units: $\frac{m^3 \text{ mil}}{m^2 \text{ day mb}}$

Trade units: $\frac{\text{std cc cm } 10^{-9}}{\text{sec cm}^2 \text{ cm Hg}}$

Table 3

PERMEABILITY OF MYLAR TO HELIUM

Temperature, T °K	Permeability, ϕ	
	$\frac{m^3\ mil}{m^2\ day\ mb}$	$\frac{std\ cc\ cm\ 10^{-9}}{sec\ cm^2\ cm\ Hg}$
300	22×10^{-7}	0.090
295	19	0.076
290	16	0.067
285	14	0.056
280	12	0.047
275	10	0.039
270	8.2	0.033
265	6.8	0.027
260	5.5	0.022
255	4.7	0.019
250	3.8	0.015
245	3.0	0.012
240	2.4	0.0095
235	1.9	0.0076
230	1.5	0.0058
225	1.1	0.0044
220	8.7×10^{-8}	0.0035
215	6.5	0.0026
210	5.0	0.0020

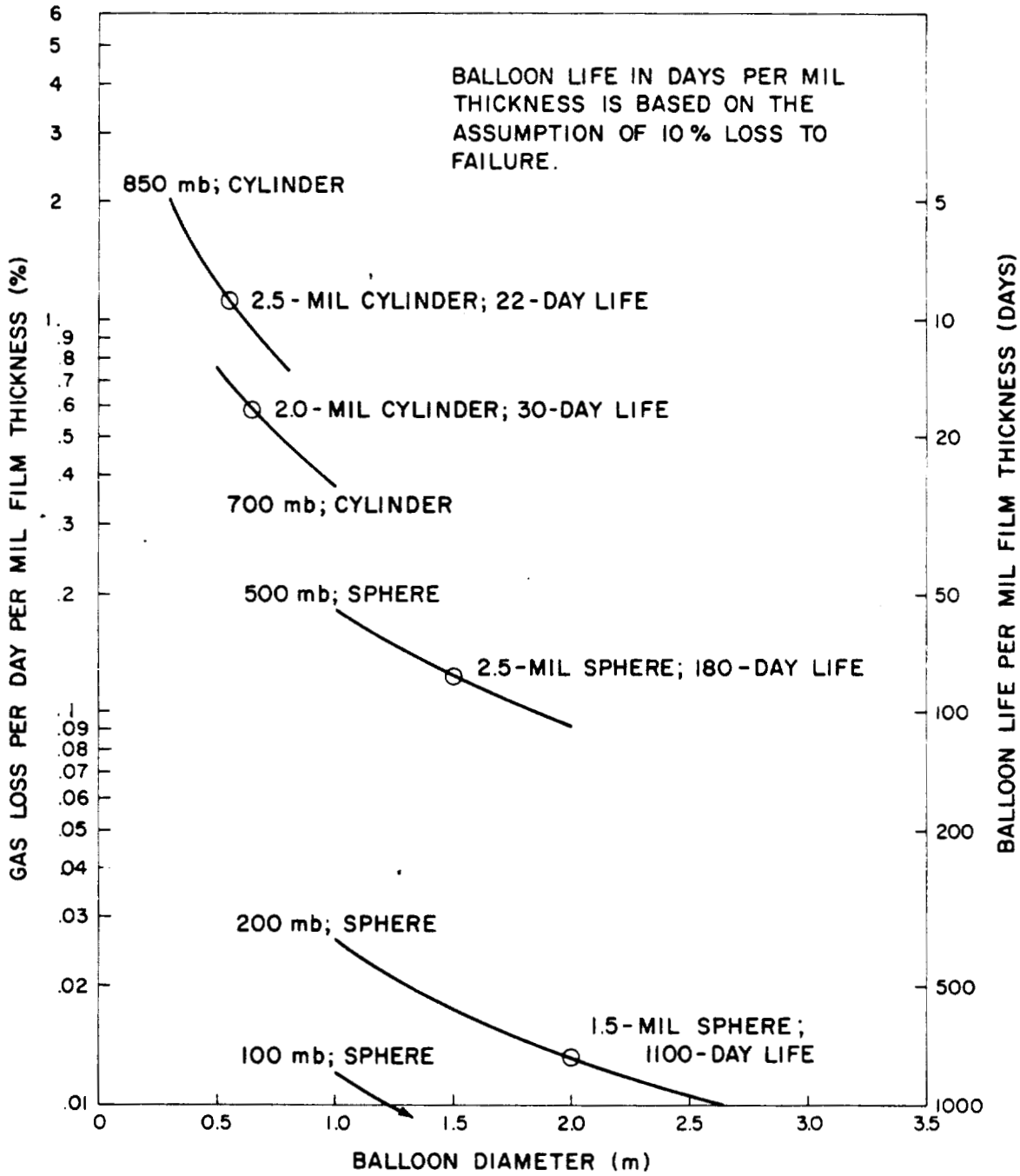


Fig. 2 Diffusion of helium through a Mylar balloon

the differential pressure, which we call either overpressure or superpressure. For "small" leaks, the flow through the orifice is molecular and is directly proportional to overpressure. For "large" leaks, the flow is proportional to the square of the overpressure. For "very large" leaks, the flow is turbulent and flow rate is proportional to the square root of overpressure. Molecular flow occurs when the mean free path of the gas molecules exceeds the largest dimension of the hole. The mean free path for helium in the lower atmosphere is at all times less than 1 micron. A 1-micron hole will not produce a significant gas loss in a superpressure balloon in a period of a year. It is possible to have many hundreds of microholes in a plastic film which could cause serious gas loss, but the technique of laminating two sheets of film in balloon construction should eliminate such imperfections. The bilaminated film can develop holes in handling, manufacture, packing, and testing, but the number of holes that are introduced should be few.

The characteristics of leaks in plastic films have not been investigated. Extensive data have been taken on leaks through vacuum systems. Table 4 is derived in part from a paper by Nerken in Ref. 2. Data are provided on hydrogen, helium, air, and Freon 12, since any of these gases may be used either in testing for leaks or as lifting gases for flight.

Table 5 indicates the per cent gas loss per day for various balloon sizes as a function of leak rate. Table 6 provides estimates of leak rate as a function of hole size and superpressure.

Using Tables 5 and 6, we can combine to estimate the percentage leak rate at several altitudes for various hole sizes (Table 7).

The most common hole size produced in handling, packing, and shipping balloons was approximately 10^{-4} m (4 mils) in diameter. These holes were easily discovered with relatively crude testing techniques. In Section IX a complete description is given of presently used testing techniques and their sensitivity for detecting pinholes.

Table 4

RELATIVE LEAKAGE RATES OF GASES FOR THREE TYPES OF LEAKS

Gas	Viscosity at 25°C (air = 1)	Molecular weight (air = 1)	Flow rate relative to air		
			Leak: very large	large	small
			Flow: turbulent	viscous	molecular
Hydrogen	0.48	0.070	3.9	2.7	3.6
Helium	1.08	0.139	2.7	1.4	2.7
Air	1.00	1.00	1.00	1.00	1.00
Freon 12	0.67	4.20	0.49	0.97	0.62

Table 5

PERCENTAGE GAS LOSS PER DAY FOR TYPICAL BALLOON SIZES
(500-mb, 200-mb, and 30-mb balloons)

Gas flow		Percentage gas loss per day		
		Balloon Diameter		
m^3/day	cc/sec	500 mb -- 1.5 m	200 mb -- 2 m	30 mb -- 6.7 m
10^{-4}	10^{-3}	0.005%	0.0025%	6×10^{-5}%
10^{-3}	10^{-2}	0.05	0.025	6×10^{-4}
10^{-2}	10^{-1}	0.5	0.25	6×10^{-3}
10^{-1}	1	5	2.5	6×10^{-2}
1	10	50	25	0.6
10	100	---	---	6
100	1000	---	---	60

Table 6

ESTIMATED LEAKAGE RATE AS A FUNCTION OF HOLE SIZE

Leak	Hole size	Gas flow m^3/day					
		$\Delta\rho$ = 30 mb		$\Delta\rho$ = 10 mb		$\Delta\rho$ = 5 mb	
		Air	Helium	Air	Helium	Air	Helium
Very small	10^{-5} m (0.4 mil)	3×10^{-4}	4×10^{-4}	10^{-4}	1.5×10^{-4}	5×10^{-5}	8×10^{-5}
Pinhole	10^{-4} m (4 mils)	3×10^{-2}	4×10^{-2}	10^{-2}	1.5×10^{-3}	5×10^{-3}	8×10^{-3}
Large	10^{-3} m (1 mm)	2	5	1	3	0.7	2
Enormous	10^{-2} m (1 cm)	175	500	100	270	70	200

Table 7

ESTIMATED GAS LOSS PER DAY FOR TYPICAL BALLOONS FOR VARIOUS HOLE SIZES

Leak	Hole size	Gas loss/day % per hole [a]			Expected life for one hole [a]		
		500 mb 1.5 m	200 mb 2 m	30 mb 6.7 m	500 mb 1.5 m	200 mb 2 m	30 mb 6.7 m
Very small	10^{-5} m (0.4 mil)	0.05%	0.01%	0.00005%	200	1000 days	200,000 days [b]
Pinhole	10^{-4} m (4 mils)	5	1	0.005	2	10	2,000
Large	10^{-3} m (1 mm)	-	120	1.2	-	1	8
Enormous	10^{-2} m (1 cm)	-	-	120	-	1	1

[a] Assume 75-mb overpressure for the 500-mb balloon, 30-mb overpressure for the 200-mb balloon, and 5-mb overpressure for the 30-mb balloon.

[b] Diffusion will limit life to 30,000 days.

V. THE RADIATION ENVIRONMENT

A. INFRARED RADIATION

We can consider the balloon and its payload in equilibrium with the radiation environment, in order to make a first estimate of temperature of the balloon skin or payload. The actual temperature will lie between the computed radiation temperature and the air temperature. At higher altitudes (above 20 km) and for large objects, the effects of air conduction and convection can be neglected.

We can estimate the radiation environment using the following simplified assumptions:

1) Downward radiation

   a) Clouds above

      - Downward flux equals blackbody radiation from a source whose temperature is the cloud base temperature (Table 8).

   b) Clear above

      - Balloon above 15 km -- 10 w/m^2
      - Balloon between 10-15 km -- 20 w/m^2
      - Balloon below 10 km -- 40 w/m^2

2) Upward radiation

   a) Clouds below

      - Upward flux equals blackbody radiation from a source whose temperature is the cloud top temperature (Table 8).

   b) Clear below

      - The upward radiation will vary from 150 w/m^2 to 450 w/m^2 depending on altitude and air mass. Table 9 provides estimates of upward flux for several altitudes and air masses.

3) Radiation from the sides

   - The radiation from the sides can be estimated as equal to blackbody radiation from a source whose temperature is the air temperature at balloon altitude (Table 8).

Table 8

RADIATION FROM A BLACK BODY AS A FUNCTION OF TEMPERATURE

Temperature (^{o}C)	Radiation flux (w/m^2)	Temperature (^{o}C)	Radiation flux (w/m^2)
200	2846	50	619
195	2728	45	582
190	2613	40	546
185	2502	35	512
180	2395	30	480
175	2291	25	449
170	2190	20	419
165	2093	15	391
160	1999	10	365
155	1908	5	340
150	1821	0	316
145	1736	-5	294
140	1655	-10	272
135	1576	-15	252
130	1500	-20	233
125	1427	-25	215
120	1357	-30	198
115	1289	-35	183
110	1224	-40	168
105	1161	-45	154
100	1101	-50	141
95	1043	-55	129
90	988	-60	117
85	934	-65	107
80	883	-70	97
75	834	-75	88
70	787	-80	79
65	742	-85	71
60	700	-90	64
55	658		

B. SOLAR RADIATION

Direct solar radiation at very high levels is 1400 w/m^2. At 100 mb direct radiation is about 1200 w/m^2. At 700 mb a figure of 1000 w/m^2 may be used. If there are clouds below the balloon, the indirect radiation reflected from the clouds may be as high as 800 w/m^2 directed upward.

At altitudes of 12 km and above, cirrus clouds rarely produce more than 10% reduction in incoming solar radiation.

C. TEMPERATURE CONTROL OF BALLOONS

Nighttime radiation temperature for a spherical balloon may be calculated from the following equation:

$$[\alpha_i + (1 - \alpha_i)\alpha_i](\Phi_D \pi r^2 + \Phi_U \pi r^2 + 2\,\Phi_S \pi r^2) = \alpha_i\ 4\pi r^2\ \Phi_r$$

where α_i is the absorptivity of the film in the infrared, Φ_D, Φ_U, Φ_S, and Φ_r are the down, up, side, and reradiated flux, respectively.

For films which are highly absorptive in the infrared, this equation simplifies to:

$$(\Phi_D + \Phi_U + 2\Phi_S) = 4\Phi_r$$

Film temperature may be computed from the reradiated flux, using Table 8.

It should be noted that the radiation temperature is independent of the absorptivity for materials which are more than 80% absorptive in the infrared.

A balloon with a reflective coating will have the same radiation temperature at night as a "black" balloon. A balloon which is relatively transparent in the infrared will have a higher radiation temperature than the black balloon, since it absorbs radiation which penetrates one side. However, the reflective balloon and the transparent balloon will each take on a temperature which is closer to the air temperature than that

of the "black" balloon, since the total energy absorbed and reradiated is much less than for the "black" balloon. A balloon with a metalized cap will operate 10 to 15°C hotter than a balloon of 100% polyester material.

The effect of the sun is to produce an increase in absorbed radiation and an increase in film temperature. The added flux absorbed from sunlight for a "transparent" balloon is:

$$\Phi_{sun}\ \alpha_o\ 2\ \pi r^2 = \Delta\Phi_r\ 4\pi r^2$$

or

$$\Delta\Phi_r = \frac{\alpha_o}{2}\ \Phi_{sun}$$

where $\Delta\Phi_r$ is the added flux reradiated, and α_o is the absorptivity in the visible spectrum.

For a polyester balloon ($\alpha_o = 0.05$), the added flux is $0.025\Phi_{sun}$. This added flux varies from a minimum of 25 w/m² for a low-altitude balloon above a water surface, to 45 w/m² for a high-altitude balloon above a continuous cloud deck. For a polyester balloon ($\alpha_1 = 0.85$), the temperature increase required to radiate 1 w/m² of flux at -50°C is 0.4°C; the temperature increase required to radiate 1 w/m² at 0°C is 0.25°C. Maximum solar heating on a high-altitude balloon (30 mb) will be 20°C, and a typical increase will be 12°C. At the lower altitudes, an average temperature increase due to solar radiation will be 8 to 10°C.

Table 9 indicates the radiation environment for several altitudes and seasons.

D. TEMPERATURE CONTROL OF ELECTRONIC SYSTEMS

Control of small electronic packages during daytime hours is a simple matter. The skin temperature of the package can be controlled within narrow limits by use of controlled surface blackness. It can be

Table 9

RADIATION ENVIRONMENT FOR SUPERPRESSURE BALLOON

Altitude	Season	Air Temperature °C	Average nighttime clear sky balloon supertemperature		Mylar balloon (α_o = 0.05)		
			Mylar balloon °C	Metalized top balloon, °C	Temperature increase per w/m² increment, °C	Maximum added solar flux w/m²	Maximum daytime temperature increase, °C
3 km (700 mb)	Temperate, winter	-10	0	+5	0.24	35	8
	Temperate, summer	5	-3	+2	0.21	35	8
	Tropic	10	-5	0	0.20	35	8
6 km (500 mb)	Temperate, winter	-30	0	+8	0.30	35	10
	Temperate, summer	-15	-5	+5	0.27	35	9
	Tropic	-5	-10	+2	0.25	35	9
9 km (300 mb)	Temperate, winter	-50	+5	+15	0.36	40	14
	Temperate, summer	-35	-5	+7	0.34	40	13
	Tropic	-30	-10	+2	0.34	40	13
12 km (200 mb)	Temperate, winter	-55	+10	+20	0.36	45	16
	Temperate, summer	-55	+10	+20	0.36	45	16
	Tropic	-50	+5	+15	0.36	45	16
16 km (100 mb)	Temperate, winter	-60	+5		0.42	45	19
	Temperate, summer	-65	+10		0.42	45	19
	Tropic	-80	+15		0.47	45	21
24 km (30 mb)	Temperate, winter	-55	-5		0.45	45	20
	Temperate, summer	-55	-5		0.45	45	20
	Tropic	-55	-5		0.45	45	20

assumed that the nighttime skin temperature will equal the air temperature, with an error which will seldom exceed $10^{\circ}C$. The largest deviation from this assumption occurs in the altitude range from 12 to 18 km where the nighttime temperature of the package will be 5 to 10° warmer than the air temperature.

If it is desired to maintain warm temperatures at night, the electronic package must contain the following:

a) An insulated container which restricts heat loss to a few watts across the temperature gradient to the cold environment.

b) A thermal mass of sufficient capacity to maintain a reasonable temperature within the container during the entire night. Water provides the best thermal mass if the system is heated sufficiently to melt all ice during daytime hours. One kilogram of water provides 93 w-hr of heating capacity through heat of fusion.

c) A combination of skin temperature control and external heating, introduced to the package during daytime hours, which is sufficient to balance the heat loss during the night.

It is possible to produce higher skin temperatures than are realized with a black body, by use of a silver sulfide coating on the package. This coating has an absorption of 80% or better in the visible but it emits at less than 30% efficiency in the infrared. A blackbody surface perpendicular to the sun will reach a temperature of $100^{\circ}C$. The silver sulfide surface, because of its poor emissivity, will reach a radiation temperature of $140^{\circ}C$. The insulation used within the container must be capable of withstanding these temperatures without deterioration. Polyurethane foam, which can withstand temperatures up to $200^{\circ}C$ without deterioration, is one of the most suitable insulating materials for use in maintaining nighttime temperatures.

It must be emphasized that any means of maintaining warmer temperatures at night requires a thermal mass and, consequently, a substantial amount of material. Such a mass might introduce hazards to aircraft. The ultimate goal in the development of electronic systems and power

sources must be a system which will operate at ambient air temperature at whatever level the balloon flies. With such systems the problem in daytime temperature control will be to minimize the solar effect so that the system will maintain a constant temperature day and night. The use of paints which are reflective in the visible, and black in the infra-red, permits such temperature control without any difficulty.

VI. BALLOON STABILITY

A. DIURNAL CHANGES IN ALTITUDE DUE TO SUPERTEMPERATURE

Equations 18 through 27 (Appendix A) derive the relationship of altitude changes to volume changes. For a polyester sphere, 1% change in supertemperature will produce a change of 0.15% in volume. Any change in volume will produce an identical change in density at which the balloon floats. A 1% change in altitude equals approximately 0.3T m in altitude, where T is temperature in $^{\circ}$K.

The altitude variation due to supertemperature change on a spherical balloon can be approximated as:

$$\Delta Z = 4.5\Delta(\Delta T)$$

As a simple approximation, we can state that a 1°C change in supertemperature will produce a 4.5-m change in altitude for a typical spherical balloon.

Variation in temperature during the day may be as much or greater for a Mylar balloon as the day-night effect. Maximum differences observed have been 6°C, but data are too limited to allow us to set realistic limits. For balloon design, a 10°C (±5°C) variation is assumed in supertemperature due to changes in the infrared environment.

Diurnal changes in altitude due to supertemperature may be summarized as:

a) A predictable day-night altitude change of 30 to 40 m.

b) An "unpredictable" variation in the radiation environment on the order of ±20 m.

B. CHANGE IN ALTITUDE DUE TO GAS LOSS

Equations 28 through 31 derive the relationship which permits a balloon to lose gas without any change in altitude. Table 10 shows the change in altitude produced by a 10% loss in gas for balloons designed to fly at several altitudes. For all practical balloon designs, the altitude change due to gas loss can be neglected.

C. CREEP

All plastic materials exhibit some degree of creep under stress. Creep is the permanent elongation of the plastic film when stressed. The relationship between stress and strain is defined by the modulus of elasticity, which is a function of temperature. Non-elastic creep is a function of stress and temperature as well, but also depends strongly on the prior history of the material.

Plastics exhibit markedly different characteristics above and below the "glass-transition" temperature: at higher temperatures they have "plastic" characteristics; at lower temperatures they behave more like a glass. Plastics creep under stress much more than glasses. The "glass-transition" temperature for polyesters is about $350^{\circ}K$ -- thus, the polyesters are "glassy" substances at all temperatures of importance in ballooning.

Tests have been conducted at room temperature on bilaminated Mylar strips to measure creep. Results are shown in Fig. 3. Creep will be less at the lower temperatures which balloons experience at float altitude.

Tentative results can be summarized as:

- Creep under moderate stress reduces with time, becoming negligible after two weeks. The time constant is about two days at room temperature for stresses between 5,000 and 10,000 psi. Total creep is 3.3% at 10,000 psi and 0.25% at 5,000 psi.
- A balloon may be prestressed to minimize creep. This procedure will also relieve stresses produced in balloon manufacture.

Table 10

ALTITUDE CHANGE WITH GAS LOSS FOR TYPICAL SUPERPRESSURE BALLOON DESIGNS

Altitude	Balloon diameter (m)	Film thickness (mils)	Altitude change for 10% gas loss (m)
6 km	1.5	3.0	+ 5
(500 mb)	1.5	2.5	-17
9 km	2.26	3.0	+13
(300 mb)	2.0	2.0	-15
12 km	2.26	2.0	+12
(200 mb)	2.0	1.5	0
16 km	3.0	1.5	+22
(100 mb)	2.5	1.0	+ 4
24 km	5.5	1.5	+15
(30 mb)	3.5	1.0	+19

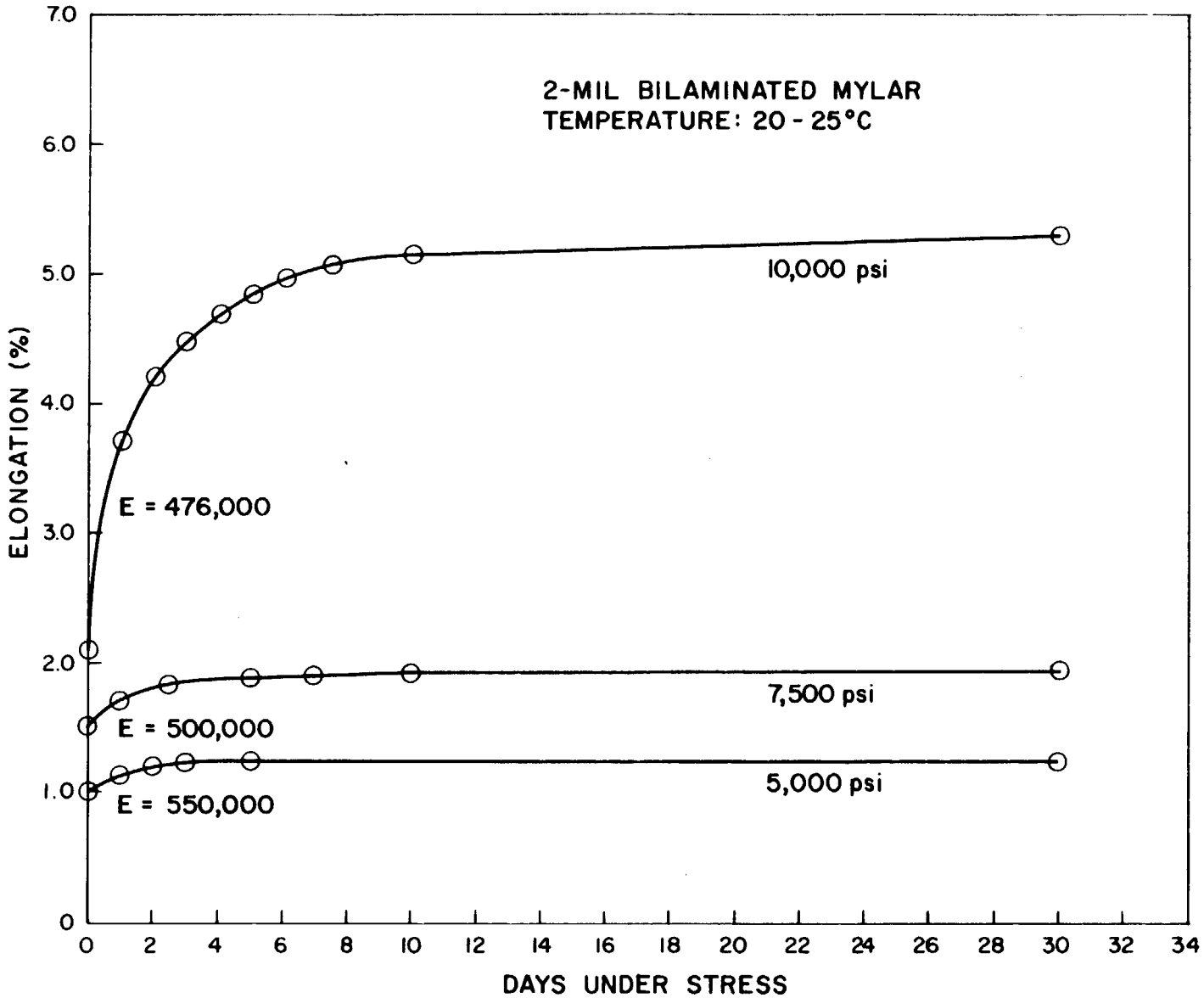


Fig. 3 Creep as a function of stress

- If a balloon is prestressed at 10,000 psi for one week at room temperature and is not stressed at float altitude beyond 7,500 psi, creep will be negligible over a period of one year.

Figure 4 shows variation in strain measured over a period of five days on a balloon floating at 500 mb. This balloon was highly stressed and showed very large creep. The time constant appears to be three days for this balloon rather than the two days observed in room temperature measurements. This apparent increase is due to the reduction of stress at night, so that only 50% of the time was the balloon stressed at the higher and more critical values above 9,000 psi.

D. ALTITUDE VARIATION DUE TO VERTICAL CURRENTS

The altitude variation for a sphere as derived in Eqs. 32 through 36 is:

$$\Delta Z = \frac{1.15\ C_D\ Tv^2}{r}$$

where

ΔZ = incremental change in altitude (m)
C_D = drag coefficient
T = temperature at Z ($^{\circ}$K)
v = vertical wind velocity (m/sec)
r = balloon radius (m)

For a prolate spheroid balloon, the equation is:

$$\Delta Z = \frac{1.15\ C_D\ Tv^2}{a}$$

where

ΔZ = incremental change in altitude (m)
C_D = drag coefficient
T = temperature at Z ($^{\circ}$K)
v = vertical wind velocity (m/sec)
a = major radius (m)

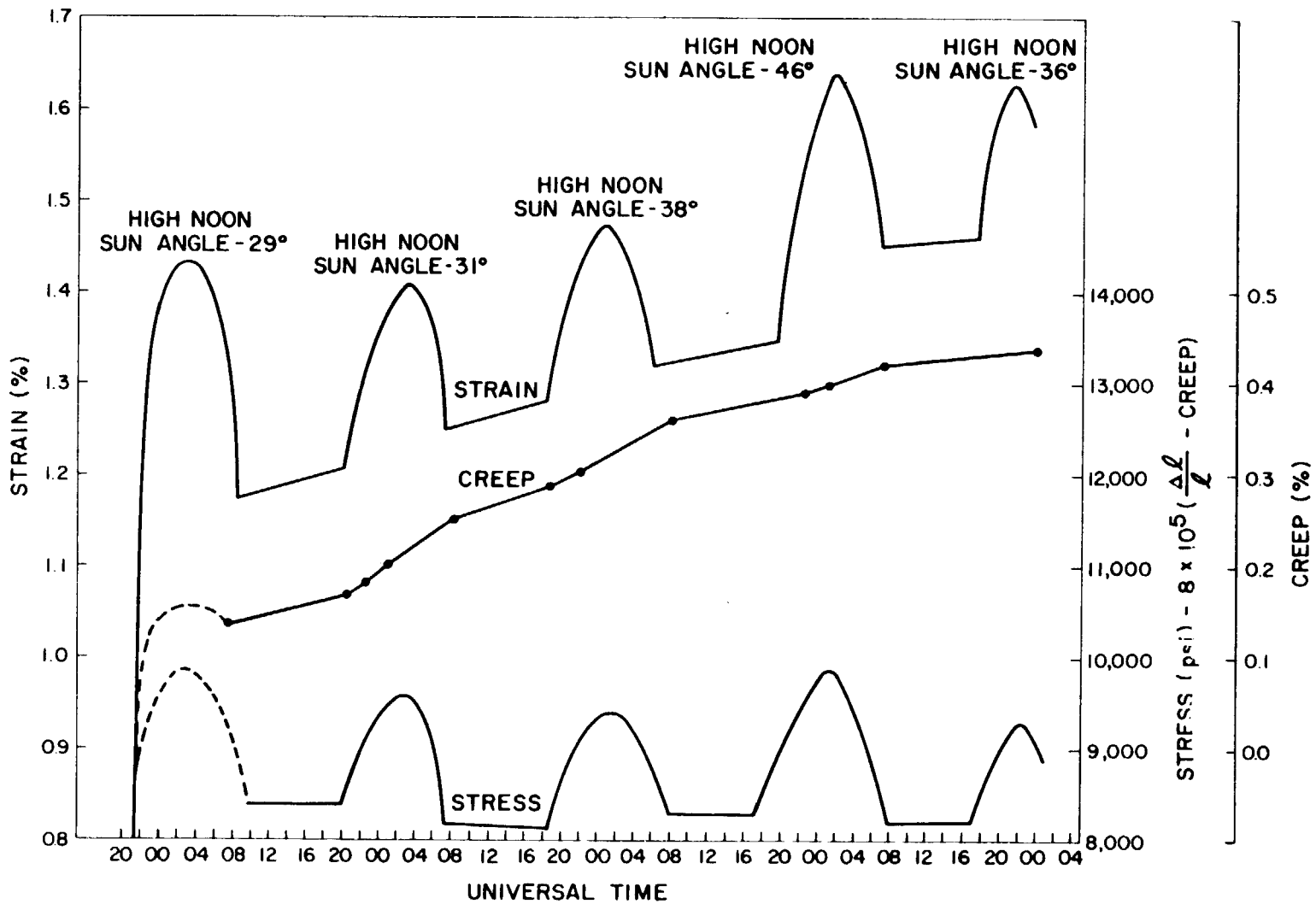


Fig. 4 Strain and stress variations on a floating balloon

Table 11 provides data on the deviation from the buoyant altitude as a function of vertical wind velocity for spheres and for a prolate spheroid with a fineness ratio of 3. The vertical excursion is negligible for vertical winds less than 0.5 m/sec for the spherical balloon, but becomes quite serious for vertical winds in excess of 1 m/sec.

At lower altitudes where convection may be severe, the balloon may move with the updrafts and downdrafts. We can make a streamlined superpressure balloon for which the response will be less than 10% of the response of an equivalent spherical balloon. The streamlined shape is recommended for all altitudes up to 700 mb. Above 700 mb the streamlined shape becomes too large and unwieldy.

E. NATURAL OSCILLATION PERIOD OF A SUPERPRESSURE BALLOON

If a superpressure balloon is displaced from its buoyant altitude, Z_s, there is a restoring force which is proportional to the balloon volume and the density difference:

$$m \frac{d^2 Z}{dt^2} = -Vg(\rho_s - \rho)$$

or

$$\frac{d^2 Z}{dt^2} = -g \frac{(\rho_s - \rho)}{\rho}$$

$$\frac{\rho_s - \rho}{\rho} = \frac{\left(P \frac{\partial T}{\partial Z} - T \frac{\partial P}{\partial Z}\right) Z}{PT}$$

$$\frac{d^2 Z}{dt^2} = \frac{-g \left(\frac{\partial T}{\partial Z} - \frac{T}{P} \cdot \frac{\partial P}{\partial Z}\right) Z}{T}$$

Table 11

ALTITUDE DISPLACEMENT OF SUPERPRESSURE BALLOONS
AS A FUNCTION OF VERTICAL WIND

Vertical wind speed (m/sec)	ΔZ (m)			
	700 mb sphere	700 mb prolate spheroid	500 mb sphere	200 mb sphere
	$C_D = 0.5$ $T = 269^\circ K$ $r = 0.75$ m	$C_D = 0.05$ $T = 269^\circ K$ $a = 1.5$ m $b = 0.5$ m	$C_D = 0.5$ $T = 252^\circ K$ $r = 0.75$ m	$C_D = 0.5$ $T = 217^\circ K$ $r = 1.0$ m
0.1	2 m	0.1 m	2 m	1.3 m
0.5	51 m	2.5 m	48 m	31.0 m
1.0	206 m	10.0 m	193 m	125.0 m
2.0	824 m	42.0 m		
5.0	5,150 m	260.0 m		

The value for T is taken from the U. S. Standard Atmosphere, 1962.

This is the familiar equation for simple harmonic motion with the period of oscillation, τ, equal to:

$$\tau = 2\pi \sqrt{\frac{T}{g\left(\frac{\partial T}{\partial Z} - \frac{T}{P} \cdot \frac{\partial P}{\partial Z}\right)}}$$

or

$$\tau = 2 \sqrt{\frac{T}{\frac{\partial T}{\partial Z} + 3.42 \times 10^{-2}}}$$

since

$$\frac{\partial P}{\partial Z} = -3.48 \times 10^{-3} \frac{P}{T} g$$

For an isothermal region $\left(\frac{\partial T}{\partial Z} = 0\right)$, the expression for period of oscillation simplifies to:

$$\tau = 11 \sqrt{T}$$

The natural oscillation period for a superpressure balloon in an isothermal atmosphere varies from 150 sec at -75°C to 180 sec at 0°C. An adiabatic lapse rate $\left(\frac{\partial T}{\partial Z} = -10^{-2}\ {}^{\circ}C/m\right)$ will increase the period by approximately 15%.

VII. SENSORS FOR USE ON SUPERPRESSURE FLIGHTS

A. TEMPERATURE

It has been assumed that the lack of ventilation on a superpressure balloon makes it difficult to measure temperature accurately. However, extensive tests by several investigators concerned with measurement of air temperature from rocketsondes have shown that above 40 km convection is not a significant factor in reducing radiation errors. At lower altitudes, errors can be made sufficiently small that the absence of forced convection is not critical. Thermistors developed for rocketsonde applications are directly useful for measurement from floating balloons at all altitudes of interest, with errors not exceeding $1^{\circ}C$.

The small metalized-bead thermistor will provide acceptable temperature measurements on a superpressure balloon to altitudes above 10 mb. Difficulties with this sensor are long-term drift effects and self-heating. The delicate lead contacts are the principal cause of long-term drift for the small bead thermistor. The small size of the bead makes it very sensitive to self-heating errors introduced from the measuring circuits. Great care must be exercised in minimizing the current flow through the bead.

We have found a 10-mil aluminized rod thermistor to be entirely satisfactory to altitudes of 30 mb. This thermistor is much less sensitive to self-heating effects and shows superior long-term stability.

The conventional ML-419 radiosonde thermistor which is 30 mils in diameter provides acceptable temperature measurements to altitudes of at least 200 mb. The lead carbonate coating on this element is black in the infrared and as a result the instrument is too sensitive to the infrared radiation environment.

The rod thermistor should be mounted vertically for superpressure balloon flight. This mounting minimizes infrared errors, since the element is "looking" at the surrounding air rather than at ground and space. This mounting is especially important for the ML-419 element. The vertical mount of the rod thermistor permits a correction (if this is considered necessary) for solar heating, since the angle of the sun can be computed at any time. With the vertical mounting a variation in apparent temperature during the day as a function of sun angle provides an accurate measurement of the total solar effect.

The most critical element in measuring temperature of a superpressure balloon is the location of the sensor. It should be located well below the balloon to prevent measurement errors caused by "chimney" currents flowing over the balloon. If the balloon is considerably colder than the atmosphere, the below-balloon mounting will introduce errors; however, this effect is important only at altitudes above 30 km where the balloon at night may be 10 or 20° colder than the air. The element should be mounted on a boom, removed from the electronic package by a distance not less than two to three times the largest package dimension. If the package is black in order to maintain daytime heating, the ML-419 element becomes unacceptable unless it can be removed completely from the influence of the package.

With care, air temperature measurements can be made to an accuracy of 0.5°C or better at all altitudes where superpressure balloons will be flown.

B. DENSITY

The superpressure balloon floats at a constant density level. Equations 39 and 40 indicate the method of determining volume, using strain gauge measurements. Density is computed from the relationship of mass to volume. Density can be computed to an accuracy of 0.25% absolute (15 m). The variation in density can be computed to 0.1% (6 m) by monitoring the variation in strain on the balloon.

C. PRESSURE

$$P = k \rho T^*$$

$$T^* = T + f\frac{es}{p} \times 0.38$$

At 500 mb the maximum virtual temperature difference ($T^* - T$) is $0.45^\circ C$. At 300 mb the maximum virtual temperature difference is $0.06^\circ C$. At higher altitudes the difference is negligible. Assuming at 500 mb or lower that humidity is estimated or measured to within 30%, humidity errors will not contribute to the pressure error. No correction is needed at higher altitudes than 500 mb.

Since density is known to 0.25% and temperature to 0.2%, the pressure is known to 0.3% accuracy (20 m).

Variations in pressure should be measurable to 0.15% (10 m).

D. THE STRAIN GAUGE/AIR TEMPERATURE COMBINATION

1. Balloon Stress

$$S = E \frac{\Delta \ell_s}{\ell_o}$$

where $\frac{\Delta \ell_s}{\ell_o}$ is the balloon strain. Note that the measured value, $\frac{\Delta \ell}{\ell}$, includes a creep factor which must be estimated.

$$\frac{\Delta \ell_s}{\ell_o} = \frac{\Delta \ell}{\ell_o} - \frac{\Delta \ell_c}{\ell_o}$$

Stress variations can be measured to 0.05% on a balloon which is no longer creeping. (Creep time constant is between two and three days.)

The absolute value of stress will not be known to better than 5% because of uncertainties in the value of E and of the absolute creep from time of original measurements of ℓ_o and V_o.

2. Balloon Superpressure

$$\Delta P = \frac{St}{r}$$

$$\Delta P = E \frac{\Delta \ell_s}{\ell_0} \cdot \frac{t}{r}$$

The value of overpressure should be known to 5% because of uncertainties in the total amount of creep. Overpressure variations can be measured to better than 0.1%.

3. Balloon Supertemperature

$$\text{Superpressure} = \begin{matrix}\text{free lift}\\ \text{superpressure}\end{matrix} + \begin{matrix}\text{supertemperature}\\ \text{superpressure}\end{matrix} - \text{gas loss}$$

$$\Delta P = \frac{F}{M} P + \left(\frac{T_g - T}{T}\right) P + \frac{\Delta M_g}{M_g} P$$

The absolute value of supertemperature is computed from superpressure, initial free lift and gas loss. Gas loss can be estimated on a long flight within 2%. Supertemperature can be measured to the accuracy of superpressure (5%). Since short-term variations in superpressure are entirely due to supertemperature, supertemperature variations can be measured to 0.1% or better.

This sensitivity should permit accurate estimates of the variation in the radiation environment.

E. WIND SHEAR

The superpressure balloon provides an ideal platform for making wind measurements. A long line may be deployed below the balloon and the wind can be measured at any point along the line. At the point which may be considered the drag center of the balloon-line system, the average wind will be zero. The balloon will be exposed to a small relative wind since it will be above this drag center. A line 3500 m long below a 300-mb balloon would permit measurement at 400 and 500 mb using

wind, temperature and pressure sensors deployed along the line. It would take a strong, weighted line, however, to probe deeply. Shorter lines can be used to measure wind shear and data can be extrapolated to lower altitudes without appreciable error, provided the balloon is flying below the tropopause. An assumption of uniform wind shear over an altitude of 3,000 m is appropriate in the altitude range of 5,000 to 10,000 m, especially in temperate latitudes during the winter season.

Table 12 indicates the level of zero wind for line lengths between 100 and 1000 m for a flight level of 400 mb, assuming a balloon with a cross section of 3 m^2 and a 6-lb breaking strength, monofilament nylon line with a diameter of 2.3×10^{-4} m. Relative wind velocity on the balloon and the bottom of the line is also indicated in terms of wind shear.

Maximum line length should not exceed 600 m because of the blow-up in line tilt at the balloon for strong shears when a longer line is used. Wind shear can be measured with a wind sensor at the line bottom or at the balloon. For a 600-m line of 6-lb strength, the shear can be measured using a formula resembling:

$$\sigma = 10^{-2} V_b$$

where σ is the shear in sec^{-1} and V_b is the balloon velocity in m/sec. Since wind velocity at the balloon will be 10^{-1} m/sec for a shear of $10^{-3} sec^{-1}$, we need a low starting speed anemometer. The simplest solution is to equip the balloon with cups. The balloon will rotate at an angular rate such that the cup speed will be about one-third wind speed. We have an ideal, frictionless anemometer.

The deployment of a 600-m line from a small superpressure balloon appears to be a formidable problem. However, the balloon and its associated electronics can be launched in the normal manner while a slack string is run off a spinning reel. If winds are strong, the line tends to drop to the ground. Judicious placement of 10-gm balloons (fastened with masking tape) along the line keeps it from falling. When the end

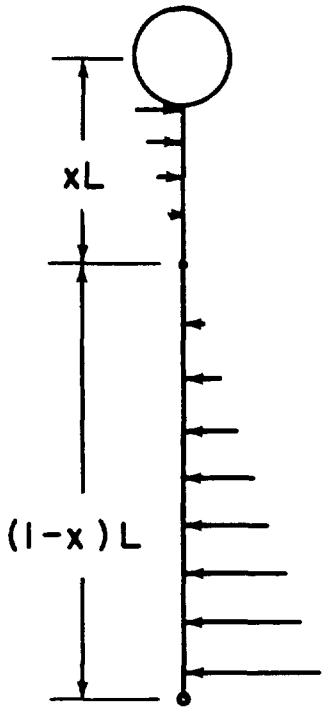
Table 12

WIND SHEAR ON LONG LINES [a]

Line length, L (m)	Fractional distance from balloon to zero shear point, x	Distance from balloon to zero wind (m)	Wind on balloon (S)	Wind on bottom of line (S)
100	0.14	14	14 [b]	86
200	0.15	30	30	170
400	0.16	64	64	336
600	0.18	108	108	492
800	0.19	152	152	648
1000	0.20	200	200	800

[a] For a balloon of 3 m^2 cross section. Nylon monofilament (6-lb breaking strength) line diameter = 2.3×10^{-4} m.

[b] S wind shear (sec^{-1}) ($S_{max} = 2 \times 10^{-2}$ sec^{-1})



of the line with its payload is reached, the payload is released on a 30-gm balloon which has a slow leak. The payload and line move off with no danger of striking the ground. As the system ascends, the 30-gm balloon loses its lift and transfers the payload to the main balloon. The 10-gm balloons shatter during ascent.

Five long-train balloon launches have been made without difficulty from a parking lot in Boulder, Colorado, in light to moderate winds using this deployment technique. Two of the launches were with balloons equipped with cup anemometers. The longest train launched was 2500 m.

F. TURBULENCE

The superpressure balloon does not provide, *per se*, a suitable platform for turbulence measurements. The balloon is moving in the air stream and does not undergo measurable accelerations for turbulence of long wavelengths. Small-scale turbulence can be measured using suitable sensors on the vehicle. For example, a black disk which was used to measure sun angle on a number of flights from Japan reached temperatures from 50 to 100°C above ambient. Small-scale turbulence produced cooling of the black disk. It was possible to correlate turbulence with the frequency and amplitude of temperature variations, but only in a qualitative manner.

The best means of measuring turbulence from the balloon platform would appear to be through measurement of wind shear over an appropriate distance, since the turbulence cells will produce a vertical wind shear which can be correlated with the vertical winds. The device can be a very sensitive indicator of turbulence for cell dimensions of the same order as the line length. The line length can be adjusted to permit measurements of clear air turbulence over the dimension range significant for aircraft operations.

VIII. MODES OF BALLOON FAILURE

A. LIQUID WATER ADHESION

Balloons flying below the freezing level can accumulate enough water on the balloon surface to overcome the free lift if the balloon is small and the surface untreated. An untreated balloon can retain as much as 50 gm of liquid water for each meter squared of surface area. However, balloons with a surface treatment such as Carnauba wax will retain no more than 5 gm/m^2 of surface. Wax treatments will undoubtedly deteriorate with time, but a chemical treatment now available will maintain the water-repelling characteristics of the balloon film surface for periods in excess of six months. With the use of surface treatments, adhesion of liquid water should not produce balloon failure.

The pressure of a continuing heavy downpour of rain can drive a spherical balloon down to the ground. A cylinder balloon is much less susceptible to this type of damage. A balloon caught in strong convection can be forced up to an altitude where it is overstressed and destroyed, or it can be forced down to the surface by a strong downdraft. The best procedure for minimizing this effect at the low altitudes is to use a shaped balloon. The improvement factor using a prolate spheroid with a fineness ratio of 3 is illustrated in Section VI, D.

B. SUPERCOOLED WATER, ICE CRYSTALS AND FROST

Reliable superpressure balloon flight has not yet been achieved in the region from the freezing level to an altitude of approximately 10 km. The freezing level can vary from ground level to an altitude of 5 km. Below the freezing level the major hazards are violent storms and mountains. Above the freezing level and below 10 km clouds contain supercooled water droplets. If a supercooled droplet touches the balloon,

it freezes instantly and adheres strongly. No methods have yet been developed which will release the ice accumulations formed by the freezing of supercooled water. Mechanical motions and chemical treatments can remove layers of ice from the balloon when the ice film has integrity, but by that time the ice load is heavier than the balloon can carry. Supercooled water exists at temperatures down to -40°. A number of investigators cite evidence of supercooled water at lower temperatures than -40°, but their findings have not been generally accepted. Above 10 km temperatures are usually below -40° and it appears a reasonable assumption that supercooled water does not pose a hazard.

At altitudes above 10 km it is possible for ice crystals to be attracted to the balloon film because of charge differences. A settling of sufficient ice crystals on the surface of the balloon could cause the balloon to descend and fail. The French have some evidence that this was the mode of failure for two balloons flying in the tropics at the altitude of 10 km.

At night the superpressure balloon is warmer than the air temperature at all altitudes between 10 and 20 km. Between 5 and 10 km the superpressure balloon is usually colder at night than the atmospheric temperature. On one flight in the tropics at an altitude of 5.5 km, the balloon was 10° colder at night than air temperature. This effect was so pronounced that the balloon temperature remained 1 to 2° colder than air temperature during daylight hours. It is apparent that a balloon in this environment can accumulate a frost coating at night even in the absence of clouds, provided the dew point is higher than the film temperature.

We do not yet know which of the three mechanisms (supercooled water, ice crystals, or frost) is the principal factor in reduction of balloon life between 5 and 10 km.

C. METHODS OF MINIMIZING FAILURE

The methods to be used in reducing flight failures between 5 and 10 km should be based on understanding of the mechanism of failure.

Lacking such knowledge, we can attempt a number of solutions: if one solution succeeds, it will help to determine the failure mode.

There are three approaches to overcome the ice problem. We can fly the balloon above the icing level with a long line permitting measurement in the areas which are not safe for balloon operation. We can permit the balloon to descend to the surface or to a lower level where it may shed the ice and return to its flight level. Or we can allow rapid ascent of the balloon above the level of icing once the danger is detected, and return to flight level at a later time. The first of these solutions is described in Section VII, F. With this technique wind shear is measured over a vertical distance of several thousand feet, permitting extrapolation to even lower levels. The other two methods are described below.

1. The Pontoon or Yoyo Balloon

The French, in preliminary project EOLE experiments, have successfully demonstrated the pontoon technique, which consists of carrying a float 100 m or more below the balloon. When the balloon ices up, it descends to the ocean surface. The pontoon has sufficient mass so that its buoyancy as it skims the water overcomes the icing load. When the ice breaks loose or melts from the balloon surface, the balloon and its pontoon will ascend again to the design float altitude.

There are two disadvantages to this scheme. It is usable only over ocean areas (in the southern hemisphere this is scarcely a disadvantage), and the balloon will probably ascend again into the same critical environment and be forced down again. A successful pontoon system must be very rugged to overcome the stresses of these repeated returns to the ocean surface. A modification of this method which will be tested on future EOLE experiments is the replacement of the pontoon with a small superpressure balloon which becomes overpressured at a very low altitude. It is hoped this system will permit the descent of the balloon to an altitude below the freezing level where it will regain its lift after shedding ice and return to design altitude. If this method performs successfully it will permit recovery over land areas and will minimize stressing of the balloon system.

2. The Cannibal-loon

An alternative to attempting to recover at lower altitude is a balloon system which will rapidly ascend above the icing level whenever icing danger is sensed. Release of ballast from a superpressure balloon will not permit the balloon to ascend unless lift gas is valved from the system. Such a solution could be used only once and there would be no way of returning the balloon to its design altitude. However, it is possible to fly a two-balloon system in which the helium-filled balloon is zero-pressure and always has an excess of volume, and the control balloon is a superpressure balloon filled with air. This air balloon can be considered an "anchor" which holds the helium balloon to a fixed altitude. If air is vented from the anchor balloon, the balloon system rises and the superpressure remains constant. If air is forced into the anchor balloon the overpressure does not increase but the balloon descends to a lower altitude. It is thus possible to control such an anchor balloon system to float at any altitude, to ascend rapidly, and to return to its design altitude, provided there is some means of pumping air back into the anchor balloon.

There are two disadvantages to this balloon system. The total surface area is larger than for a single balloon, thus increasing the area on which ice may form; and the balloon system when uncontrolled floats at a higher altitude during daytime hours than at night, since the supertemperature of the helium balloon during daytime provides additional lift which can only be overcome by moving the anchor balloon to a higher altitude where its apparent weight increases.

Both defects can be overcome by swallowing the helium balloon within the superpressure anchor balloon -- thus the name "cannibal-loon."

Since the system volume is constant, the cannibal-loon will float at a constant density altitude at all times in the absence of venting or pumping. This system has a number of other advantages:

- The balloon can be launched fully inflated, permitting test prior to launch in inflated condition. Launch can be made in high winds without balloon damage. Brittle materials such as metals and glass can be used.

- The helium membrane is not overpressured and pinholes will not cause gas loss. The membrane can be made of material with low permeability for helium regardless of material strength.

- The outer film may have leaks without affecting performance. (A leak causes the balloon to go up.)

- With the use of an air pump the balloon can be lowered to any desired altitude. When pumping stops, it will fly at a constant density surface.

- With the use of a valve the balloon can be raised quickly to any desired altitude. When icing is sensed, the balloon can quickly rise to a higher altitude out of the icing environment. It can be pumped down during daylight hours to its assigned altitude after it has moved out of the icing area.

The manner of operation of the cannibal-loon is as follows:

a) The balloon is launched fully inflated with a valve open, permitting air to be exhausted as the balloon ascends.

b) The valve is closed by a pressure switch when the balloon reaches its design altitude.

c) When danger is indicated by a 100% humidity detection, the valve is reopened and the balloon ascends until it is out of the danger area.

d) During daylight hours a simple air pump is operated, forcing the balloon back to its design altitude. This air pump is operated at all times when the ice sensor indicates "no danger," as long as the balloon remains above its design altitude.

A simple air pump has been designed, consisting of a rigid rotating chamber with half its surface black. One-way valves bring air into the chamber and force air into the balloon. Rotation is most easily obtained by slowly turning the entire balloon system. Tests are underway on designs which will not be a hazard to aircraft. The pump will take up to two days to return the balloon to a 400-mb level if it has escaped to 200 mb. This delay is not a disadvantage, since it is better to delay return until the balloon has moved far from the danger area. This procedure will permit a much more rapid and efficient deployment

of balloons around the hemisphere from a single launch site than can be achieved if balloons are always flying at the design level where wind speeds may be lower.

This technique can provide a programmed radiosonde-type reading during ascent and an accumulation of long-term average data over the entire altitude range during the slow descent, provided that communications and location are controlled from a geostationary satellite.

A metalized cap on a polyester balloon will increase the nighttime temperature by 10 to 15°K if skies are clear above. If a principal failure mechanism is the collection of frost when the film temperature drops below the dew point on a clear night, the metalized cap covering one-third of the film area may provide the necessary margin of safety to prevent frost accumulation.

IX. BALLOON TESTING TECHNIQUES

There are two basic kinds of tests for balloons: integrity tests which determine whether the balloon is a tight vehicle or not, and leak detection tests in which the objective is to determine the specific location of leaks so that they may be repaired.

A. INTEGRITY TESTS

Integrity tests can only be justified if a majority of the balloons which are tested successfully pass the test. If most balloons fail the test, it is essential that leakage tests be made to determine the specific location of leaks. If most of the balloons do have leaks, it would appear appropriate to run a leak detection test prior to an integrity test. A major advantage of the integrity test is the assurance, if a balloon passes, that no leaks above a threshold level exist in the balloon. There is always the chance in a leak detection test that a leak may be overlooked.

Three types of integrity tests have been used to date:

1. Helium Lift Tests

This test procedure is useful only for small balloons and requires one to two days. The balloon is inflated with helium in a cold room so that it is slightly underpressure. The lift of the balloon is then measured. Measurements are repeatable to an accuracy of 0.1 gm for 2000 gm lift, if there is no air motion in the room and if the wall temperature and air temperature are in equilibrium. The balloon is then moved to a warm room where it overpressures. The balloon loses gas through diffusion and through pinhole leaks. After not less than one day, the balloon is returned to the cold room and the lift measured again. During this period gas diffusion can be as high as 0.25% but

this diffusion should be known within 0.02%. If a number of identical balloons are tested, diffusion corrections can be made to as close as 0.01%. The loss of gas in excess of diffusion is assigned to leakage. With proper procedures leakage can be measured to 0.02%, provided the cold room is a stable environment.

The advantage of this test method is that the balloon can be flown without deflation and reinflation, simply by removing the excess helium. The disadvantages are that full helium inflation is difficult with balloons larger than 2 m diameter, and that it is expensive to provide a stable, cold-room environment for large balloons.

2. Overpressure Test

This test procedure requires at least one week to provide leakage measurements better than 0.1%, because of balloon creep and the difficulty of making exact measurement of volume change. The procedure is to measure atmospheric pressure, air temperature, balloon overpressure and balloon volume. Fractional loss of gas due to leakage can be computed by adding fractional loss of pressure, fractional loss of overpressure, fractional loss in volume and fractional gain in temperature. The advantage of this test procedure is that monitoring is simple (a single measurement each day suffices) and, if air is used as the inflation gas, diffusion can be neglected. The disadvantage is the marginal accuracy of the technique which requires a long time period and a high space utilization. To minimize large changes in overpressure the test should be made in a room in which temperature is well controlled, since the balloon exhibits hysteresis effects in change of volume with change of stress.

3. Tent Test

The tent test consists of inflating a balloon with air and Freon to a large overpressure. The balloon is placed for not less than twenty-four hours under a plastic tent. If the balloon has leaks, Freon will accumulate in the tent and can be readily detected by a halogen detector. If properly conducted, the tent test is probably more sensitive than the other two integrity tests. However, the test

is not quantitative and it is difficult to use the results to compare relative integrity of balloons.

B. LEAKAGE TESTS

Leakage tests are much more burdensome than integrity tests but they may be conducted more quickly.

1. Visual, Hand and Ear Inspection

If overpressure in the balloon exceeds 10 mb, leaks from holes 1 mm (40 mils) in diameter or larger are easily detected visually or by the sound of escaping gas. If the hole cannot be seen, its exact location can usually be discovered by running the wrist across the suspected area.

2. Ammonia-Wet Cloth Method

With this technique ammonia is introduced into the balloon together with air, and the balloon is overpressured. A cloth which has been soaked in phenolphthalein solution is placed over the balloon. Leaks produce reddish spots on the cloth where the ammonia reacts with the phenolphthalein solution. The sensitivity of this technique is not known.

3. Freon Detection

Freon is introduced into the balloon together with air, and the balloon is overpressured. A standard halogen detector is used, with a funnel over the detector to increase the inspection area. Holes 0.1 mm (4 mils) in diameter are readily detected. With careful technique in a clean room, 1-mil holes can be detected. The major disadvantage with this technique is the time required -- about ten minutes inspection time per square meter of surface.

4. Helium Detection

The balloon can be completely filled with helium or, if it is a large balloon, filled with a helium-air mixture and leaks detected with a device sensitive to helium. The mass spectrometer is not suitable

for this application since it is too sensitive and will respond to diffusion of helium through the walls of the balloon. Also, a major leak will saturate this system and requires extensive purging before work can be continued.

A helium detector now on the market operates on the principle of thermal conductivity. This device balances background air against sample air and can be used in an atmosphere which has a high helium concentration. It appears a most promising method, with about the same sensitivity as the halogen detector; however, the concentration of helium in the balloon can be raised to at least ten times the level that is economical for Freon concentration. This technique should permit the conductivity device to out-perform the halogen detector.

5. Bubble Detection

This technique has been used very successfully on the French EOLE project. A plastic wading pool is filled with water and detergent is added. The balloon is floated in the pool and visual inspection detects bubbles in the area which is underwater. This technique detects larger holes very quickly -- only one or two minutes are required for careful inspection per square meter of area. It should be capable of detecting holes of 0.1 mm (4 mils) diameter when some care is used.

C. FACTORY TESTING

At present it is essential that balloons be tested in the field prior to launch because of damage which may occur in packing and shipping, or because of the inability of the manufacturer to make valid integrity tests in an economical fashion. Larger balloons pose very difficult problems for field testing, because of the difficulty of handling, and because large enough facilities for conducting tests are seldom available.

There appears to be no inherent reason that balloons can not be packed, shipped and handled without damage. For any large-scale operational program, field testing is impossible. It is essential that techniques be developed at the factory to insure that the balloon as

delivered to the launch site is free of defects. A major development program is required to attain this capability. What is required is a development effort in which the manufacturer will fabricate, test, pack, ship, unpack, and retest balloons and repeat this cycle until he can give assurance that balloons as delivered are without defect. This closed cycle is necessary because of the very long delay in determining balloon integrity through flight tests. As the closed cycle continues, the manufacturer will learn to improve his testing techniques and handling and packing procedures. After the balloon is tested it may be necessary to treat it with special preservative coatings which are removed just prior to flight, or it may be necessary to develop new laminates containing one or more layers of soft plastic which will not be subject to handling damage.

X. BALLOON MATERIALS

A. DESIRED CHARACTERISTICS FOR BALLOON MATERIALS

The ideal balloon film would have a very large modulus of elasticity (10 million psi), and would be transparent to the entire spectrum of radiation from infrared to ultraviolet. Such a material would not need high ultimate strength since it would never be highly stressed. The material, in addition, should be easily formed so that a balloon could be manufactured out of few spherical sections. It should be readily sealed with seal strengths as high as the strength of the basic material. The material should be impermeable to helium, oxygen, nitrogen, and water vapour. In addition, it should be plastic at room temperature so that it could be readily packed without damage. At floating altitude, the material could well be glassy so that it would shatter if struck by an aircraft.

No existing material comes close to meeting these ideal specifications. However, at least one material does come sufficiently close to providing an acceptable film for fabricating superpressure balloons. This is the polyester, polyethylene terephthalate.

B. MINIMUM SPECIFICATIONS FOR BALLOON MATERIALS

Most plastic materials fall short of the minimum specifications in one characteristic or another, so that they cannot provide a long-lived, stable vehicle. The minimum specifications to permit flight are interrelated; for example, a material that has great strength, but at the same time is highly absorbent of solar radiation, will be over-stressed by the pressure buildup caused by supertemperature. A weaker film may survive if it is sufficiently transparent. The minimum specifications for a balloon material are indicated in the following sections.

1. Modulus of Elasticity

A balloon with an insufficient modulus of elasticity will stretch as it superpressures, if the volume increase due to stretch is sufficient to move the balloon to a higher altitude so that the stress is maintained. The balloon will continue to ascend until it bursts in the same fashion as neoprene and rubber balloons. The minimum modulus of elasticity for an acceptable balloon depends on the free lift introduced in the balloon and on the supertemperature which the balloon will realize at floating altitude. All materials with a modulus of elasticity less than 300,000 psi are unacceptable for superpressure use. This minimum modulus applies at the temperature at floating altitude. A number of film materials have too low a modulus at room temperature or at lower floating altitudes, but are acceptable at higher altitudes where the film temperature is -30°C or lower. A realistic minimum modulus of elasticity for a plastic film with average transparency is 500,000 psi. The higher the modulus, the more stably the balloon will fly and the less the variation in altitude will be between night and day. A balloon with a modulus of 800,000 psi will have an altitude change of 30 to 40 m between day and night. A modulus of 10 million psi would reduce the altitude change between night and day to an insignificant amount.

2. Strength of the Balloon Material

Modulus of elasticity is a much more important characteristic of balloon film than ultimate film strength, provided the balloon is never stressed beyond its elastic limit. A lighter material may have a lower ultimate strength than a more dense material, since a thicker film may be used. For example, a polypropylene, which is 40% less dense than polyester, can provide a stronger material for balloon design than polyester, even though its strength is somewhat lower. An acceptable film strength for superpressure design depends on flight altitude, payload weight, and density of the film. As a general rule, the film material should be capable of stresses to 10,000 psi in its elastic range, while maintaining an acceptable modulus of elasticity.

3. Transparency

Balloon films vary markedly in their transparency to solar and infrared radiation. The ideal material should be transparent to the entire spectrum of solar and earth radiation. Of the several plastic materials which approach this ideal, polyethylene comes closest, absorbing less than 6% of the radiation through the solar infrared band. Polyester film approaches polyethylene transparencies at solar wavelengths, but is almost black in the infrared. As a result, for a balloon made of polyester variations in internal heating due to variations in the atmospheric radiation environment are larger than those due to night and day differences.

It may be assumed that a metalized balloon would have ideal characteristics. However, the best values of reflectivity achieved with metalized balloons have been about 94% for solar radiation and 99% for infrared radiation. The infrared emmissivity of the metalized film is 1%, and so the balloon film becomes very hot when solar input is maximum. The metalized balloon, in general, is inferior in radiation characteristics to a clear balloon at higher altitudes. For lower altitude flights, a metalized balloon will provide improved characteristics over a thick-walled semitransparent balloon. Conduction then becomes the basic mechanism removing excess heat acquired by the balloon's inefficiency as an infrared emitter.

No complete theory has been worked out which will permit computation of the amount of supertemperature experienced by a balloon in flight. The effectiveness of conduction and convection in removing heat from a balloon at float altitude can only be estimated at present. The simplest procedure for obtaining these data is to conduct flight tests of instrumented balloons with measurements of air temperature and lifting gas temperature.

4. Formability

The ideal film material should be readily formed into a hemisphere, or at least a large sector of a sphere, by heat or pressure in a die or mold. Most plastics can be so formed. However, the more readily they

can be formed in this fashion the poorer they usually are as a balloon material. Polyethylene terephthalate film, a polyester, which is the best of the available balloon materials, is cast in sheet form and is drawn into other forms with great difficulty. As a result, the balloons used presently for superpressure flight are made from a large number of flat gores to simulate a sphere. The sealing tapes add considerable weight and increase the chances of leaks.

The optimum characteristic for formability would be a material which can be blown into a spherical shape in the same manner as rubber balloons or glass bulbs. However, attempts to blow large glass forms have failed because of the brittleness of the material. All the plastics which have been successfully formed by blowing have been completely inadequate in strength and modulus. It is conceivable that thin-walled glass balls may be blown using helium instead of air to provide a lighter-than-air sphere. We would need then only to enclose thousands of these balls in a netting to provide our superpressure balloon system.

5. Brittleness

Since superpressure balloons will be flown in the air lanes, it is essential that the balloon material either shatter or tear easily. A number of plastic materials have a sufficiently high "glass transition temperature" that they become glass-like at flight temperatures. Polyethylene terephthalate is one of these materials, with a glass transition temperature above 70°C. Although this polyester has ten times the strength of polyethylene, it has only about one-tenth the tear resistance. Since the balloon is never shocked during testing, inflation, launch, or flight there is no need for high tear resistance.

However, the glassy materials present a major problem in manufacture, packing, and unpacking. Creases in the material can cause holes. A double fold, one transverse to the other, in a glassy material provides a sharp point which can tear another section of the film or cause a pinhole at the point of intersection. To prevent such defects the balloon could be assembled at the launch site, but this is not usually feasible. Perhaps the problem will be solved by making sure that the

balloon is handled, packed, unpacked, and inflated, at high room temperatures so that the material has more plastic characteristics.

6. Sealability

Many plastics, such a polyethylene, can be heat-sealed using simple techniques. The seals have over 90% of the strength of the plastic material. Polyesters and polypropylene are not easily sealed to themselves and require tape seals with a thermal-setting adhesive. Tape seals are more difficult and costly, but they do provide additional strength to the balloon.

Any seal should be gas-tight and provide at least equivalent strength to the basic material.

7. Permeability

Most plastics serve as quite adequate gas barriers for a one-day flight. However, few existing plastic materials have low enough permeability to permit extended flight using either helium or hydrogen. It is not sufficient that the balloon film have low permeability just for helium and hydrogen. Its permeability for nitrogen, oxygen, and water vapour must also be sufficiently low that there is no appreciable transfer of air into the balloon during flight. All the materials under consideration do have much lower permeability to nitrogen and oxygen than to hydrogen and helium.

For extended flights of superpressure balloons, helium is the only acceptable filling gas. Ammonia exacts too great a weight penalty in balloon design. Hydrogen is unacceptable because of explosion hazard, both during testing and also after the balloon returns to earth at the end of its flight, when the possibility of air mixing with hydrogen, makes an even greater hazard.

The best existing plastic for helium retention is cellophane. Saran ranks second, and polyester (polyethylene terephthalate) ranks third. Few other plastics have acceptable helium permeability characteristics at warmer temperatures. However, among plastics diffusion depends greatly upon temperature, and polyethylene and polypropylene

become acceptable at temperatures below -30°C. As a rule of thumb, for long-duration flights the rate of diffusion through a plastic material should be less than 10^{-6} m^3 mil/m^2 per day per millibar (4×10^{-11} std cc cm per sec per cm^2 per cm Hg pressure).

XI. LOCATION TECHNIQUES

GHOST balloons and their payloads must be non-hazardous to aircraft. In addition, the need for both light weight and low cost (in a system involving thousands of balloons) indicates that the balloon payload must consist of the simplest possible electronic system. The systems flown successfully so far weigh 100 gm and cost $100. However, the location accuracy has been an order of magnitude less than the accuracy required for an operational system.

Interrogation by satellite provides the opportunity of enhancing location accuracy without a substantial increase in balloon electronic complexity. To date, unfortunately, the emphasis in development of balloon-satellite electronics has been on reliability rather than simplicity, and all the systems under present development are too heavy, too complex, and too costly.

A. HIGH FREQUENCY DIRECTION FINDING (HFDF)

The classical method of locating balloons has been high frequency direction finding at 3 to 15 Mc. The more sophisticated balloon systems have used two frequencies to provide optimum transmission day and night. Fixes are obtained by combining several simultaneous bearings from widely separated stations. The Federal Communications Commission has a direction-finding network which locates transmitters to an accuracy of 20 to 50 km from the middle Pacific to the eastern Atlantic. Adcock antennas provide bearings of 1° or better. However, long baselines limit accuracy with high-frequency direction finding and even a network operated by experts such as maintained by the FCC is saturated if more than ten targets are to be tracked.

B. SUN ELEVATION ANGLE

If the sun elevation angle is telemetered from a balloon, the balloon can be located as lying on a circle, the center point of which lies directly below the sun. If a second elevation angle is measured at a later time, a new circle can be determined. The intersection of these two circles provides a location, provided that the balloon has not moved. However, if the velocity of the balloon is not known, there is no unique position fix and position can only be estimated. If the elevation angle of the sun is monitored continuously through the day, a series of lines of position can be determined and a reasonably accurate fix obtained. The position determination is unique only if some assumption is made as to the balloon's velocity, such as constant velocity or constant acceleration. Experience obtained in more than 80 flights in the southern hemisphere indicates that position can be estimated to an accuracy between 50 and 100 km if data have been obtained on sun angle for several hours. The technique is, of course, only usable during daylight and at times when there are no clouds above the balloon. Thin cirrus clouds affect angle determination at low sun angles but do not cause serious errors in sun angle measurements at high sun elevation angles. Reference 3 provides a complete description of the technique for measuring and telemetering sun angle information.

C. HFDF AND SUN ELEVATION ANGLE

In a combined location system employing sun elevation angle and high-frequency direction finding, simultaneous lines of position are obtained and there is no need for a balloon velocity correction. Since the circle of position lines of the sun elevation angle is moving and changing in size, at some time during the day it is possible to get a good intersection between the high-frequency bearing and the sun elevation circle. The problem of having enough HFDF stations over a large area to provide good intersects is avoided and it is only necessary to have sufficient stations so that at least one station can obtain a bearing during the day. The advantage of this technique over the sun elevation angle alone has been demonstrated many times by cooperating

radio operators equipped with Adcock antennas who have tracked test flights of the GHOST system. The accuracy of this combined system will not exceed the accuracy of sun elevation angle alone, except where gross errors are made in the assumptions about balloon velocity. This combined technique requires much more complex equipment and a much larger number of installations to cover a hemisphere.

D. LORAN C

It is possible to provide a 100-kc receiver on the superpressure balloon and retransmit on a high-frequency link the Loran C signals received aboard the balloon, to provide accurate position location. The technique has been demonstrated by the U. S. Weather Bureau with radiosondes. Unfortunately, the Loran C networks cover only areas of heavy aircraft traffic and there is presently no Loran C coverage in the southern hemisphere.

E. OMEGA

The OMEGA very low frequency location system is, like Loran, a hyperbolic system; however, it operates in the 10 to 14 kHz range and eight stations will provide global coverage. It is theoretically possible to receive OMEGA signals on a balloon and retransmit the signals back to a ground station to obtain location of the balloon. However, since each of the stations is multiplexed, any variation in the transmission time back to the ground station will introduce serious errors. Consequently, OMEGA signals can be used with high frequency retransmission only if phase comparisons are performed at the balloon platform prior to retransmission. The signal-to-noise ratio of the received OMEGA signals is such that this appears most difficult at this time.

We do not yet know whether OMEGA will be implemented on a global basis. There are presently only four substandard stations -- Norway, Trinidad, New York, and Hawaii. They provide an adequate area for testing but the utilization of OMEGA remains in doubt until a national decision is made to implement.

F. SATELLITE TECHNIQUES

Satellites can be used in three ways to locate GHOST balloons. First is the use of a geostationary satellite as a simple command and communications relay, with other techniques being used to provide the balloon location. For example, the OPLE (OMEGA Position Location Equipment) now under limited development at Goddard Space Flight Center locates the balloon by transmitting the OMEGA signals back through a geostationary satellite to a ground computer which determines the balloon location. There are a number of major problems in providing absolute position for balloons using the OMEGA stations because of possible confusion in identity of the correct lane. The system does provide extremely precise relative position over short periods of time. We can conceive a system in which the balloon's absolute position is determined once a day within 50 km, using simple sun elevation angle sensors. The velocity would be determined every two hours by transmitting OMEGA information back through the synchronous satellite, and absolute position could be obtained by dead reckoning until the next sun elevation angle position was obtained. The requirement for meteorology is to ascribe an accurate velocity to a rather large area, i.e., a block 300 km on a side. If this velocity is obtained by sequential absolute positions, then these positions must be known with great accuracy. However, if the velocity can be obtained in some manner independent of the absolute position, the 300 km location accuracy is sufficient for all meteorological needs concerned with the general circulation.

A second means of obtaining location via satellite is to use a low-orbiting satellite which locates the balloon by successive measurements, each of which provides a line of position. Since the satellite is moving rapidly, lines obtained one or two minutes apart will have good intersects and need only small corrections for balloon motion. The IRLS system under development at the National Aeronautics and Space Administration determines position by two successive range measurements. The EOLE system under development in France provides position by two successive measurements of doppler shift which give information on the angle between satellite and balloon. The system proposed in the National

Academy of Sciences report (Ref. 4) is similar in concept to the IRLS location method. These systems are capable of determining balloon position to an accuracy of 1 to 2 km. Velocity is determined by positions obtained on successive orbits of the satellite (every two hours).

Almost one-third of the globe is under continuous view of the geostationary satellite, giving it an inherent advantage over the low-orbiting satellite. Data can be obtained from balloons in the observed area whenever desired. This coverage permits more frequent interrogation in areas of major interest; it permits verification by a second interrogation when data may be questionable; and it permits the monitoring of data which are required in a continuous fashion, such as from a balloon which is making a vertical radiosonde ascent. The difficulty with the geostationary satellite is that it is so far away that position location from the satellite is much more difficult than from a low-orbiting satellite. However, there are two feasible means of obtaining direct position data from the geostationary satellite. The first is the use of an interferometer to provide accurate angle of transmission from an interrogated balloon. The angle must be resolved to 15" of arc to permit location within 2 km, which would be a tour de force at the fringes of the state of the art. Such a system would place, of course, the minimum requirement on the balloon. It would merely interrogate and telemeter its information plus a pure tone for angle determination.

The third means, which could be used with the geostationary satellite, would be determination of range between balloon and satellite. Since range determination provides a circle of position, it would be necessary to utilize two synchronous satellites within line of sight for each balloon. Five satellites would be needed to provide global coverage. The rate of range change is very low directly below the satellite. However, this region of coarse data consists of a circle of only 100 mi diameter directly below the satellite -- a negligible portion of the globe.

APPENDIXES

List of Symbols 67

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SYMBOLS

A	balloon surface area, m^2
A'	balloon cross section, m^2
a	radius of major axis of a spheroid
b	radius of minor axis of a spheroid
C_D	coefficient of drag
E	modulus of elasticity, psi
e_s	saturation water vapor pressure, mb
F	free lift, kg
f	free lift ratio (F/M)
f	relative humidity
g	acceleration of gravity (9.8 m/sec^2)
ℓ	cylinder length, m
ℓ_o	original length of strain gauge
$\frac{\Delta \ell}{\ell}$	fractional change in length due to strain
$\frac{\Delta \ell_s}{\ell}$	fractional change in length due to stress
$\frac{\Delta \ell_c}{\ell}$	fractional change in length due to creep
M	mass of balloon, payload and lifting gas, kg
M_f	mass of gas which provides free lift, kg
m	molecular weight of lifting gas
n	number of moles of gas at Z_s
P	atmospheric pressure, mb
P_g	gas pressure, mb
P_{gs}	gas pressure at Z_s, mb
P_o	atmospheric pressure at Z_o, mb
P_s	atmospheric pressure at Z_s, mb
p	partial pressure of gas, mb
ΔP	superpressure, mb
ΔP_T	superpressure due to supertemperature, mb

ΔP_f	superpressure due to free lift, mb
R	gas constant
r	balloon radius, m
S	stress, psi
T	atmospheric temperature, $^{\circ}K$
T_g	temperature of enclosed gas, $^{\circ}K$
T_o	temperature at Z_o, $^{\circ}K$
T_s	temperature at Z_s, $^{\circ}K$
T^*	virtual temperature
t	thickness of balloon envelope, mils
ΔT	supertemperature, $^{\circ}K$
V	balloon volume, m^3
v	vertical wind velocity, m/sec
ΔV	change in balloon volume
Z_o	altitude at which balloon becomes fully inflated, m
Z_s	altitude at which balloon is in static equilibrium, i.e., floating altitude, m
ΔZ	incremental change in altitude, m
α	factor relating strain to volume change ($\alpha = 3$ for uniform sphere)
δ	permeability constant, $(m^3\ mil)/(m^2\ mb\ day)$
ϵ^2	$1 - (b/a)^2$
ρ_o	air density at Z_o, kg/m^3
ρ_s	air density at Z_s, kg/m^3
$\rho_{\Delta Z}$	air density at $\Delta Z \pm Z_s$, kg/m^3
σ	wind shear, sec^{-1}

Conversions to MKS Units

1 mb = 10^3 dyne/cm^2 = 10^2 kg/(m/sec^2)

1 psi = 69 mb

1 mil = 25×10^{-6} m

Appendix A

EQUATIONS FOR BALLOON DESIGN AND BALLOON PERFORMANCE

SUPERPRESSURE DUE TO FREE LIFT

At a density level of ρ_o, the superpressure balloon becomes completely inflated. The balloon still retains its free lift. Neglecting supertemperature and film expansion, the expression for equilbrium at this point is:

$$V\rho_o = M + F \tag{1}$$

At float altitude, ρ_s, where the balloon is neutrally buoyant, we have:

$$V\rho_s = M \tag{2}$$

dividing Eq. (1) by Eq. (2):

$$\frac{\rho_o}{\rho_s} = 1 + \frac{F}{M} \tag{3}$$

$$f \equiv \frac{F}{M} \tag{4}$$

combining Eqs. (3) and (4):

$$\frac{\rho_o}{\rho_s} = 1 + f \tag{5}$$

Using the equation of state, $\rho = kP/T$, Eq. (5) can be expressed as:

$$\frac{P_o T_s}{P_s T_o} = 1 + f \tag{6}$$

The lifting gas pressure, P_{gs}, equals the pressure at Z_0 where the balloon becomes full, corrected for temperature change.

$$P_{gs} = P_0 \frac{T_s}{T_0} \tag{7}$$

substituting in Eq. (6)

$$\frac{P_{gs}}{P_s} = 1 + f \tag{8}$$

or:

$$f = \frac{P_{gs} - P_s}{P_s} = \frac{\Delta P_f}{P_s} \tag{9}$$

or:

$$\boxed{\text{superpressure due to free lift} = \Delta P_f = fP_s} \tag{10}$$

SUPERPRESSURE DUE TO SUPERTEMPERATURE

The equation of state for the enclosed gas of a constant-volume balloon floating at altitude may be expressed as:

$$P_g V = n R T_g \tag{11}$$

Since there is no change in volume or mass, we can simplify:

$$P_g = k T_g \tag{12}$$

and for small pressure changes due to temperature changes:

$$\frac{\Delta P_T}{P_g} = \frac{\Delta T}{T_g} \tag{13}$$

or:

$$\boxed{\frac{\Delta P_T}{P_s + \Delta P_f} = \frac{\Delta T}{T_g}} \tag{14}$$

STRESSES ON A SPHERE PRODUCED BY SUPERPRESSURE

For a sphere the stress expressed in consistent units is:

$$S = \frac{r\ \Delta P}{2t}$$

If stress is expressed in psi, radius in meters, pressure in millibars, and balloon film thickness in mils, the equation becomes:

$$S = \frac{286\ r\ \Delta P}{t} \tag{15}$$

$$\Delta P = \Delta P_f + \Delta P_T \tag{16}$$

Combining Eqs. (10) and (16):

$$S = \frac{286\ r\ P}{t}\left[f + (1 + f)\frac{\Delta T}{T}\right] \tag{17}$$

DIURNAL CHANGES IN ALTITUDE DUE TO SUPERTEMPERATURE

The volume of a superpressure balloon does not remain constant. As the internal pressure increases, the stress on the film increases; consequently, volume increases. The expression relating stress, S, to strain, $\Delta\ell/\ell$, is the modulus of elasticity, E:

$$E \equiv \frac{S}{\Delta\ell/\ell} \tag{18}$$

For a spherical balloon, the volume change for small changes is three times the linear change in dimension:

$$\frac{\Delta V}{V} = \frac{3\Delta\ell}{\ell} \tag{19}$$

(For a cylinder balloon, the volume change is twice the linear change.) The volume change for a spherical balloon can be expressed by combining Eqs. (18) and (19):

$$\frac{\Delta V}{V} = \frac{3\ S}{E} \tag{20}$$

Since we are concerned with changes in volume due to changes in stress rather than the total volume change from no stress, the equation can be written as:

$$\frac{\Delta(\Delta V)}{V} = \frac{3\Delta S}{E} \tag{20a}$$

Using Eqs. (14) and (15) and combining them with Eq. (20a), we can derive an expression for the volume change due to change in supertemperature:

$$\frac{\Delta(\Delta V)}{V} = \frac{3}{E} \times \frac{286\ r}{t} \times \frac{\Delta(\Delta T)\ (P_s + \Delta P_f)}{T} \tag{21}$$

If we assume a spherical balloon design which produces 10,000 psi stress at 25% superpressure, we can obtain a "ball-park" figure for the variation of volume with supertemperature changes. From Eq. (14) we learned that a 1% increase in supertemperature produces a 1% increase in superpressure. For the typical design we consider here, an increase of 1% in the superpressure produces a 400 psi increase in stress. We can express this as:

$$\Delta S \approx 400 \times 100\ \frac{\Delta(\Delta P)}{P} \approx 400 \times 100\ \frac{\Delta(\Delta T)}{T} \tag{22}$$

substituting in Eq. (20a):

$$\frac{\Delta(\Delta V)}{V} \approx \frac{3 \times 4 \times 10^4}{E} \cdot \frac{\Delta(\Delta T)}{T} \tag{23}$$

Using the value of 8.0×10^5 psi for the modulus of elasticity of Mylar, we have:

$$\frac{\Delta(\Delta V)}{V} \approx \frac{1.2 \times 10^5}{8.0 \times 10^5} \cdot \frac{\Delta(\Delta T)}{T}$$

$$\approx 0.15 \frac{\Delta(\Delta T)}{T} \tag{24}$$

A change in volume will produce an identical change in the density at which the balloon floats. A 1% change in density equals approximately 0.3T m in altitude, where T is the air temperature in $^{\circ}$K.

The altitude variation due to supertemperature change on a spherical balloon can be roughly written as:

$$\Delta Z \approx 0.3T \frac{\Delta\rho}{\rho} 100 \approx 0.3T \frac{\Delta(\Delta V)}{V} 100$$

$$\approx 30T \frac{\Delta(\Delta V)}{V} \tag{25}$$

Using the value derived in Eq. (24):

$$\Delta Z \approx 30T \times 0.15 \frac{\Delta(\Delta T)}{T} \tag{26}$$

Thus:

$$\boxed{\Delta Z \approx 4.5\ \Delta(\Delta T)} \tag{27}$$

CHANGE IN ALTITUDE DUE TO GAS LOSS

At launch a superpressure balloon is filled with sufficient gas to provide a free lift, f, in excess of the gas required for buoyant flight. The mass of this gas is:

$$M_f = f\ V\ \rho_s \frac{m}{28.9} \tag{28}$$

During the life of the balloon, this excess gas diffuses. If we assume the balloon descends at the time that all free-lift gas has been lost, the change in balloon system mass is:

$$\Delta M = M_f \tag{29}$$

The percentage mass loss is:

$$\frac{100\ \Delta M}{M} = \frac{100\ f\ V\ \rho_s\ \frac{m}{28.9}}{V\ \rho_s} = 100\ f\ \frac{m}{28.9} \tag{30}$$

For a helium-filled balloon having 10% free lift, the percentage mass loss is:

$$\text{Percentage mass loss} = 100\ f\ \frac{m}{28.9} = 100 \times 0.1 \times \frac{4}{28.9} = 1.4\%$$

This 1.4% mass loss would cause the balloon to float (near the end of its useful life) at a level 1.4% lower in density than its original float level. However, the overpressure due to free lift decreases as the free-lift gas is lost. This decrease in overpressure causes a reduction in volume which tends to balance out the mass loss.

We can design the balloon so that the mass loss exactly balances the loss in free-lift superpressure. Basically, the technique requires that the volume loss caused by a percentage reduction in overpressure equals the mass loss produced by the same percentage loss in free lift. Combining Eq. (20) with Eq. (15), we get:

$$\frac{\Delta V}{V} = \frac{3S}{E} = \frac{3}{E} \cdot \frac{286\ r}{t}\ \Delta P = \frac{3}{S} \cdot \frac{286\ r}{t}\ f\ P_s$$

Equation (30) established:

$$\frac{\Delta M}{M} = f\ \frac{m}{28.9}$$

As discussed above, we want:

$$\frac{\Delta V}{V} = \frac{\Delta M}{M}$$

Thus:

$$\frac{858\ r\ f\ P_s}{E\ t} = \frac{f\ m}{28.9} \tag{31}$$

For a helium-filled sphere:

$$\frac{r}{t} = \frac{4\ E}{28.9 \times 858 \times P_s} \tag{31a}$$

Assuming $E = 8 \times 10^5$, then:

$$\frac{r}{t} = \frac{162}{P_s} \tag{31b}$$

Thus if the ratio of r/t is equal approximately to $162/P_s$ for a Mylar balloon filled with helium, the gas loss during the life of the balloon will not change the altitude.

ALTITUDE VARIATION DUE TO VERTICAL CURRENTS

The drag of a balloon in a vertical current is:

$$\text{Drag} = \tfrac{1}{2}\ C_D\ A'\ \rho_s\ v^2 \tag{32}$$

The restoring force can be expressed as:

$$\text{Restoring force} = V\ (\rho_s - \rho_{\Delta Z})\ g \tag{33}$$

We can use the excellent approximation from Eq. (25), that the density-difference height, ΔZ, above or below the buoyant density, ρ_s, is:

$$\Delta Z \approx 30\ \frac{\Delta\rho}{\rho_s}\ T \tag{25}$$

$$(\rho_s - \rho_{\Delta Z}) \equiv \Delta\rho$$

or

$$(\rho_s - \rho_{\Delta Z}) = \frac{\Delta Z \rho_s}{30T} \tag{34}$$

Substituting Eq. (34) in Eq. (33) and equating restoring force to drag, we have:

$$\frac{C_D\ A'\ \rho_s\ v^2}{2} = \frac{V\ \Delta Z\ \rho_s\ g}{30T} \tag{35}$$

Solving for ΔZ:

$$\Delta Z = \frac{15\ C_D\ T\ v^2}{g} \cdot \frac{A'}{V} \tag{35a}$$

For a sphere, this equation reduces to:

$$\boxed{\Delta Z = \frac{1.15\ C_D\ T\ v^2}{r}} \tag{36}$$

For a prolate spheroid balloon, Eq. (35a) becomes:

$$\boxed{\Delta Z = \frac{1.15\ C_D\ T\ v^2}{a}} \tag{37}$$

<u>DENSITY COMPUTATIONS USING A STRAIN GAUGE</u>

$$\rho = \frac{M}{V} \tag{38}$$

$$V \equiv V_o + \Delta V \tag{39}$$

$$\Delta V \equiv \alpha\ \frac{\Delta \ell}{\ell_o}\ V_o \tag{40}$$

$\frac{\Delta \ell}{\ell_o}$ is the strain measurement as telemetered from the balloon. The factor relating strain to volume change is α. (For a homogeneous sphere, $\alpha = 3$.)

Combining Eqs. (38) and (40):

$$\rho = \frac{M}{V_o + \alpha \frac{\Delta \ell}{\ell_o} V_o} \tag{41}$$

Since M is known to 0.1%, V_o is known to 0.1%, and $\alpha \frac{\Delta \ell}{\ell_o}$ is measured to 0.2% absolute and 0.1% relative, the density, ρ, can therefore be computed to 0.25% absolute (15 m).

The variation in density can be computed to 0.1% (6 m) since there is no change in V_o, and M (even for a leaky balloon) will not change by more than 0.03% per day.

Appendix B

SUMMARIES FOR BALLOON FLIGHTS

from

CHRISTCHURCH, NEW ZEALAND

March 1966 -- March 1967

The data for 85 balloons flown from Christchurch, New Zealand, and McMurdo Station, Antarctica, during the period March 1966 -- March 1967 are summarized on the following pages. Seven of these balloons are presumed still flying on 10 June 1967.

CODE FOR
GHOST BALLOON FLIGHT SUMMARY SHEETS

Balloon # nnPPf

Frequency 15.02f MHz

Method of leak test Referenced

Test results test techniques are discussed in Section IX.

Mfr. balloon #

Balloon mass gm

Balloon volume m^3

Balloon diameter m

Film thickness mils

Electronics mass Includes sensors.

Ballast Includes radar reflector, tapes and strings.

Gross weight less helium gm

Free lift gm

Launch site 172° 32'E, 43° 29'S

Launch time UT

Ascent rate

0 - 5,000 m m/sec

5,000 - 10,000 m m/sec

Float altitude m

Radar (when tracked by Christchurch Cossar radar)

Computed

Calibration data

Sun angle--Code period (10^{-1} sec)

(GHOST calibration chart follows; it can be used by drawing straight lines between calibration points.)

(Sensor cut-off Occulting angle from sun by balloon)

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m From Cossar radarsonde

5,000 - 10,000 m flight closest to

10,000 m - altitude launch time.

Altitude

Flight duration * days

Flight duration ** balloon days

Number of orbits

Position last heard QLLℓℓ

Balloon days tracked

Remarks:

* To last time of signal pick-up.

** Balloon gains one day for each west to east orbit.

nn -- number of flight. Flights 01-02, 03-04, 09-10, 16-17, 19-20 were single flights with 2 transmitters.

PP -- pressure altitude in tens of millibars

f -- last digit of frequency in kHz.

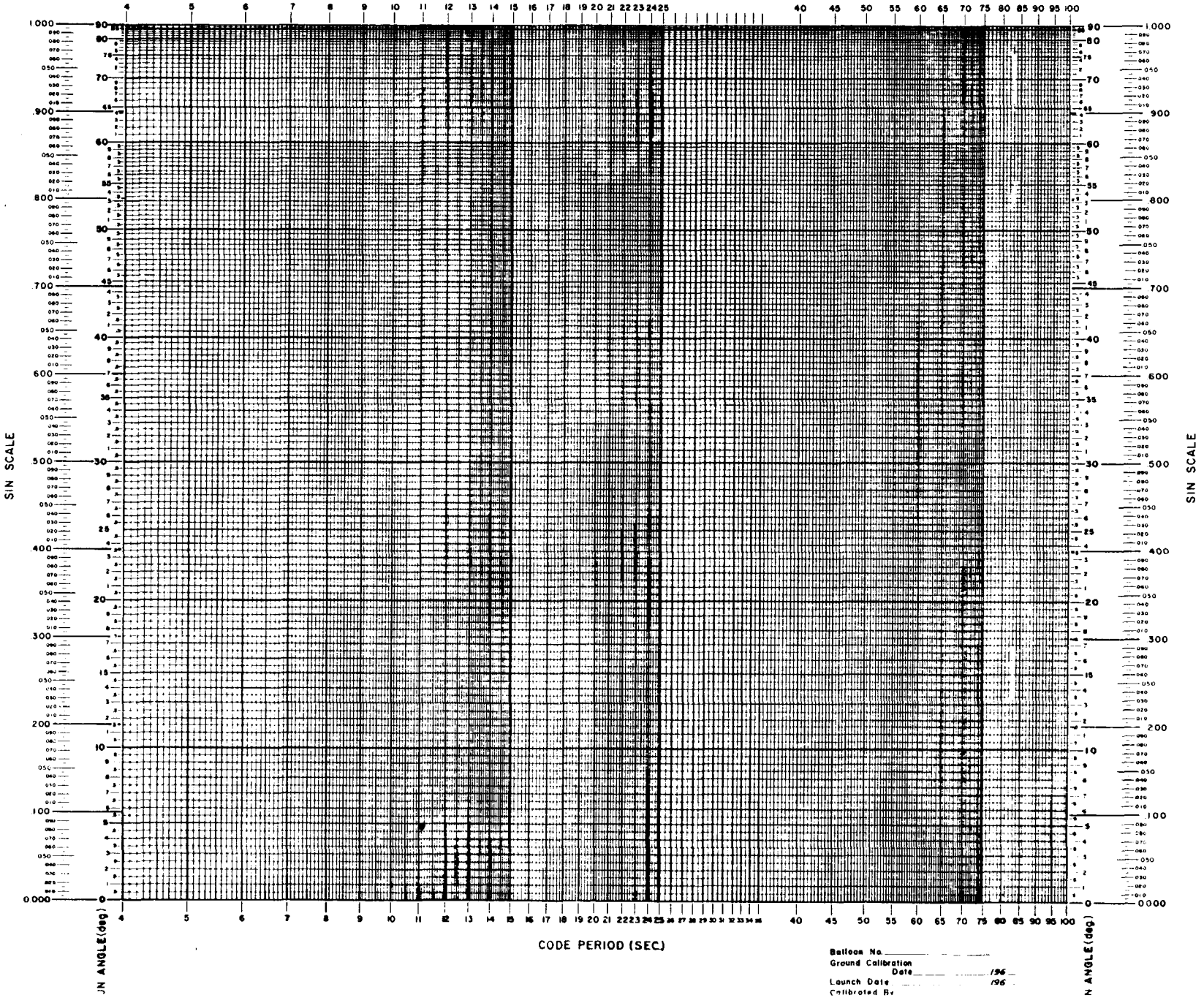
Q -- quadrant of globe, southern hemisphere

5 -- 0 to 90° West longitude
6 -- 90 to 180° West longitude
7 -- 180 to 90° East longitude
8 -- 90 to 0° East longitude

LL -- latitude in degrees

ℓℓ -- longitude in degrees

GHOST CALIBRATION CHART



GHOST BALLOON FLIGHT SUMMARY

Balloon # 01505 V 02503 U

Frequency 15.026 15.024 MHz

Method of leak test helium lift

Test results less than .03% per day

Surface winds ° calm m/sec

Cloud cover scattered altostratus

Climb-out winds 1700 UT

0 - 5,000 m 220° 13 m/sec

5,000 - 10,000 m

10,000 m - altitude

Altitude 230° 25 m/sec

Mfr. balloon # Viron 6

Balloon mass 984 gm

Balloon volume 2.26 m^3

Balloon diameter 1.63 m

Film thickness 2.5 mils

Electronics mass 202 gm

Ballast 154 gm

Gross weight less helium 1340 gm

Free lift 134 gm

Launch site 172° 32'E, 43° 29'S

Launch time 04/03/66 1650 UT

Ascent rate

0 - 5,000 m 1.25 m/sec

5,000 - 10,000 m m/sec

Float altitude 5550 m

Radar

Computed xxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	36.8
30°	21.0
83°	11.3
83°	Occulting angle

Flight duration 4 days

Flight duration 4 balloon days

Number of orbits 0

Position last heard 63072 (08/03/66)

Balloon days tracked 4

Remarks: V transmitter telemetered sun angle; U the internal temperature of the electronics package. The thermal helmet had four 1-cm diameter holes to reduce the temperature.

Maximum electronics temperature during the flight was +24°C; minimum temperature was -2°C; average temperature was +10°C.

Probable cause of failure: ice accretion on balloon film.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 03505 W 04506 B

Frequency 15.025 15.027 MHz

Method of leak test helium lift

Test results less than .02% per day

Surface winds 030° 2 m/sec

Cloud cover clear

Climb-out winds 1900 UT

0 - 5,000 m 240° 6 m/sec

5,000 - 10,000 m

10,000 m - altitude

Altitude 240° 11 m/sec

Mfr. balloon # Viron 5

Balloon mass 984 gm

Balloon volume 2.26 m^3

Balloon diameter 1.63 m

Film thickness 2.5 mils

Electronics mass 208 gm

Ballast 148 gm

Gross weight less helium 1340 gm

Free lift 134 gm

Launch site 172° 32'E, 43° 29'S

Launch time 05/03/66 1749 UT

Ascent rate

0 - 5,000 m 1.25 m/sec

5,000 - 10,000 m m/sec

Float altitude 5550 m

Radar

Computed xxx

Flight duration 5+ days

Flight duration 5+ balloon days

Number of orbits 0

Position last heard 65225 (10/03/66)

Balloon days tracked 5

Remarks: Both transmitters telemetered sun angle. Forty-five-gram corner reflector included in ballast.

Since South American stations were not yet in operation, flight duration was probably longer than 5 days.

Probable cause of failure: ice accretion on balloon film.

Calibration data 03505 W 04506 B

Sun angle--Code period (10^{-1} sec)

03505 W		04506 B	
10°	41.2	10°	35.0
30°	24.6	30°	19.9
83°	13.5	86°	10.7
83°	Occulting angle	86°	

GHOST BALLOON FLIGHT SUMMARY

Balloon # 05507 R

Frequency 15.027 MHz

Method of leak test helium lift

Test results less than .04% per day

Surface winds ° m/sec

Cloud cover

Climb-out winds 1900 UT

0 - 5,000 m 220° 15 m/sec

5,000 - 10,000 m

10,000 m - altitude

Altitude 230° 28 m/sec

Mfr. balloon # Viron 3

Balloon mass 984 gm

Balloon volume 2.26 m^3

Balloon diameter 1.63 m

Film thickness 2.5 mils

Electronics mass 105 gm

Ballast 251 gm

Gross weight less helium 1340 gm

Free lift 134 gm

Flight duration 13 days

Flight duration 13 balloon days

Number of orbits 0

Position last heard 62768 (20/03/66)

Balloon days tracked 13

Remarks: Probable cause of failure: ice accretion on balloon film.

Launch site 172° 32'E, 43° 29'S

Launch time 07/03/66 1804 UT

Ascent rate

0 - 5,000 m 1.25 m/sec

5,000 - 10,000 m m/sec

Float altitude 5550 m

Radar

Computed xxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	37.8
30°	22.4
83°	12.4
83°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 06508 K

Frequency 15.028 MHz

Method of leak test helium lift

Test results less than .03% per day

Surface winds ° m/sec

Cloud cover

Climb-out winds 1900 UT

0 - 5,000 m 220° 15 m/sec

5,000 - 10,000 m

10,000 m - altitude

Altitude 230° 28 m/sec

Mfr. balloon # Viron 2

Balloon mass 984 gm

Balloon volume 2.26 m^3

Balloon diameter 1.63 m

Film thickness 2.5 mils

Electronics mass 105 gm

Ballast 251 gm

Gross weight less helium 1340 gm

Free lift 134 gm

Launch site 172° 32'E, 43° 29'S

Launch time 07/03/66 1808 UT

Ascent rate

0 - 5,000 m 1.25 m/sec

5,000 - 10,000 m m/sec

Float altitude 5550 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10°	39.3
30°	23.8
83°	13.3

83° Occulting angle

Flight duration 19 days

Flight duration 19 balloon days

Number of orbits 0

Position last heard see remarks

Balloon days tracked 8

Remarks: Balloon last heard 14/03/66 position 63669. On 26/03/66 balloon tracked for 20 min from Pretoria, not possible to set position.

Balloons 05507 R and 06508 K were launched 4 min apart. After 7 days the balloons were separated by 200 km. On the 8th day they moved 600 km apart.

Probable cause of failure: balloon icing.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 07502 G

Frequency 15.022 MHz

Method of leak test helium lift

Test results less than .03% per day

Surface winds ° calm m/sec

Cloud cover high cirrus

Climb-out winds 2300 UT

0 - 5,000 m 270° 20 m/sec

5,000 - 10,000 m

10,000 m - altitude

Altitude 270° 30 m/sec

Mfr. balloon # Schjeldahl 3

Balloon mass 881 gm

Balloon volume 1.853 m^3

Balloon diameter 1.524 m

Film thickness 2.5 mils

Electronics mass 104 gm

Ballast 119 gm

Gross weight less helium 1104 gm

Free lift 110 gm

Launch site 172° 32'E, 43° 29'S

Launch time 10/03/66 0003 UT

Ascent rate

0 - 5,000 m 1.25 m/sec

5,000 - 10,000 m m/sec

Float altitude 5550 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10°	36.2
30°	20.5
83°	11.4
83°	Occulting angle

Flight duration 1 days

Flight duration 1 balloon days

Number of orbits 0

Position last heard

Balloon days tracked 1

Remarks: Balloon was launched after frontal passage. Winds were 30 m/sec at float altitude; apparently carried balloon into squall line during night.

Probable cause of failure: balloon icing.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 08504 F

Frequency 15.024 MHz

Method of leak test helium lift

Test results less than .02% per day. Leak in end cap section repaired.

Surface winds ° calm m/sec

Cloud cover high cirrus

Climb-out winds 2300 UT

0 - 5,000 m 270° 20 m/sec

5,000 - 10,000 m

10,000 m - altitude

Altitude 270° 30 m/sec

Mfr. balloon # Viron 8'

Balloon mass 984 gm

Balloon volume 2.26 m^3

Balloon diameter 1.63 m

Film thickness 2.5 mils

Electronics mass 106 gm

Ballast 250 gm

Gross weight less helium 1340 gm

Free lift 134 gm

Launch site 172° 32'E, 43° 29'S

Launch time 10/03/66 0020 UT

Ascent rate

0 - 5,000 m 1.25 m/sec

5,000 - 10,000 m m/sec

Float altitude 5550 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	33.8
30°	18.3
83°	10.3
83°	Occulting angle

Flight duration 1 days

Flight duration 1 balloon days

Number of orbits 0

Position last heard

Balloon days tracked 1

Remarks: Balloon was launched after frontal passage. Winds were 30 m/sec at altitude; apparently carried balloon into squall line during night.

Probable cause of failure: balloon icing.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 09505 H 10505 N

Frequency 15.025 15.025 MHz

Method of leak test helium lift

Test results less than .1% per day

Surface winds ° calm m/sec

Cloud cover clear

Climb-out winds 1700 UT

0 - 5,000 m 210° 10 m/sec

5,000 - 10,000 m

10,000 m - altitude

Altitude 216° 13.75 m/sec

Mfr. balloon # Schjeldahl 19

Balloon mass 869 gm

Balloon volume 1.853 m^3

Balloon diameter 1.524 m

Film thickness 2.5 mils

Electronics mass 208 gm

Ballast 27 gm

Gross weight less helium 1104 gm

Free lift 121 gm

Launch site 172° 32'E, 43° 29'S

Launch time 12/03/66 1805 UT

Ascent rate

0 - 5,000 m 1.35 m/sec

5,000 - 10,000 m m/sec

Float altitude 5520 m

Radar xxxx

Computed

Flight duration 13 days

Flight duration 13 balloon days

Number of orbits 0

Position last heard 63055 (25/03/66)

Balloon days tracked 13

Remarks: Both transmitted sun angle data. Accurate radar track at altitude shows no altitude variation for a period of 12 min after reaching altitude.

Probable cause of failure: balloon icing.

Calibration data 09505 H

Sun angle--Code period (10^{-1} sec)

10°	42.2
30°	25.9
83°	14.2
83°	Occulting angle

10505 N

10°	39.2
30°	24.6
86°	13.4
86°	

GHOST BALLOON FLIGHT SUMMARY

Balloon # 11503 M 12504 A

Frequency 15.023 15.024 MHz

Method of leak test helium lift

Test results less than .1% per day

Surface winds ° m/sec

Cloud cover

Climb-out winds 1700 UT

0 - 5,000 m 250° 6 m/sec

5,000 - 10,000 m

10,000 m - altitude

Altitude 073° 8.1 m/sec

Mfr. balloon # Schjeldahl 18

Balloon mass 877 gm

Balloon volume 1.853 m^3

Balloon diameter 1.524 m

Film thickness 2.5 mils

Electronics mass 207 gm

Ballast 20 gm

Gross weight less helium 1104 gm

Free lift 121 gm

Flight duration 7 days

Flight duration 7 balloon days

Number of orbits 0

Position last heard 64831 (22/03/66)

Balloon days tracked 7

Remarks: Both transmitted sun angle data. Altitude variation for 25 min radar track at altitude was less than 30 m.

Probable cause of failure: balloon icing.

Launch site 172° 32'E, 43° 29'S

Launch time 15/03/66 1805 UT

Ascent rate

0 - 5,000 m 1.35 m/sec

5,000 - 10,000 m m/sec

Float altitude 5540 m

Radar xxxx

Computed

Calibration data 11503 M

Sun angle--Code period (10^{-1} sec)

10°	38.4
30°	22.3
83°	12.3

83° Occulting angle

12504 A

10°	41.0
30°	24.3
86°	13.1

86°

GHOST BALLOON FLIGHT SUMMARY

Balloon # 13518 L

Frequency 15.028 MHz

Method of leak test helium lift

Test results less than .03% per day

Surface winds ° m/sec

Cloud cover

Climb-out winds 1700 UT

0 - 5,000 m 240° 3 m/sec

5,000 - 10,000 m

10,000 m - altitude

Altitude 070° 2 m/sec

Mfr. balloon # Schjeldahl 12 gore

Balloon mass 1020 gm

Balloon volume 1.853 m^3

Balloon diameter 1.524 m

Film thickness 3.0 mils

Electronics mass 104 gm

Ballast 5 gm

Gross weight less helium 1129 gm

Free lift 135 gm

Flight duration 6 days

Flight duration 6 balloon days

Number of orbits 0

Position last heard 64363 (23/03/66)

Balloon days tracked 6

Remarks: Probable cause of failure: balloon icing.

Launch site 172° 32'E, 43° 29'S

Launch time 17/03/66 1819 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m m/sec

Float altitude 5380 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10°	40.3
30°	24.1
83°	13.7
83°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 14507 VKUM

Frequency 15.027 MHz

Method of leak test helium lift

Test results less than .1% per day

Mfr. balloon # Schjeldahl 20

Balloon mass 876 gm

Balloon volume 1.853 m^3

Balloon diameter 1.524 m

Film thickness 2.5 mils

Electronics mass 128 gm

Ballast 100 gm

Gross weight less helium 1104 gm

Free lift 121 gm

Launch site 172° 32'E, 43° 29'S

Launch time 22/03/66 1830 UT

Ascent rate

0 - 5,000 m 1.4 m/sec

5,000 - 10,000 m m/sec

Float altitude 5770 m

Radar xxxx

Computed

Calibration data KKK

Sun angle	Code period (10^{-1} sec)
10°	38.8
30°	23.6
80°	12.7
80°	Occulting angle

Surface winds ° m/sec

Cloud cover

Climb-out winds 2300 UT

0 - 5,000 m 270° 3 m/sec

5,000 - 10,000 m

10,000 m - altitude

Altitude 280° 7 m/sec

Flight duration 1 days

Flight duration 1 balloon days

Number of orbits 0

Position last heard

Balloon days tracked 1

Remarks: V reference, K sun angle, U helium temperature, M air temperature. Believe feed-through fitting on inflation valve leaked. Ground test of equivalent feed-through subsequently showed leaks.

Maximum supertemperature +6°C at sun angle of 46°. Minimum supertemperature -5°C at sun angle of 10°. Clouds produced an 8°C change in supertemperature near noon, from +6°C to -2°C.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 15253 D

Frequency 15.023 MHz

Method of leak test

Test results Raven: not tested

Schjeldahl: not tested

Mfr. balloon # Raven 128 Schjeldahl special

Balloon mass R 965 S 1068 gm

Balloon volume R 4.19 S 1.86 m^3

Balloon diameter R 2.0 S 1.52 m

Film thickness R 1.5 S 3.0 mils

Electronics mass 105 gm

Ballast 10 gm

Gross weight less helium 2148 gm

Free lift 129 gm

Launch site 172° 32'E, 43° 29'S

Launch time 24/03/66 1826 UT

Ascent rate

0 - 5,000 m 1.25 m/sec

5,000 - 10,000 m 1.25 m/sec

Float altitude 10,900 daytime m
9,600 nighttime

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10°	38.0
30°	22.8
80°	12.5
80°	Occulting angle

Surface winds 090° 3 m/sec

Cloud cover

Climb-out winds 1700 UT

0 - 5,000 m 270° 6 m/sec

5,000 - 10,000 m 280° 11 m/sec

10,000 m - altitude

Altitude 270° 17 m/sec

Flight duration 4 days

Flight duration 4 balloon days

Number of orbits 0

Position last heard 64838 (28/03/66)

Balloon days tracked 4

Remarks: Anchor balloon flight with lower balloon providing a variable ballast for the top balloon at all altitudes above 340 mb.

Untested top balloon probably had a leak since over half of similar tested balloons later showed leaks.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 16202 S 17206 U

Frequency 15.022 15.026 MHz

Method of leak test air pressure

Test results less than .1% per day

Mfr. balloon # Schjeldahl 6

Balloon mass 978 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 209 gm

Ballast 42 gm

Gross weight less helium 1229 gm

Free lift 111 gm

Launch site 172° 32'E, 43° 29'S

Launch time 30/03/66 0023 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m m/sec

Float altitude m

Radar

Computed

Calibration data

Sun angle--Code period (10^{-1} sec)

Occulting angle

Surface winds 020 ° 6 m/sec

Cloud cover broken altocumulus

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Flight duration days

Flight duration balloon days

Number of orbits

Position last heard

Balloon days tracked

Remarks: Balloon rose to 5000 m at 1.5 m/sec, iced up, and descended at 1.5 m/sec. Temperature at maximum altitude was -8°C. S measured electronics temperature; U was sun angle.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 18185 L

Frequency 15.025 MHz

Method of leak test air pressure

Test results less than .1% per day

Surface winds 060° 7 m/sec

Cloud cover broken altostratus

Climb-out winds 2300 UT

0 - 5,000 m 280° 12 m/sec

5,000 - 10,000 m 330° 20 m/sec

10,000 m - altitude 320° 25 m/sec

Altitude 340° 22 m/sec

Mfr. balloon # Schjeldahl 8

Balloon mass 984 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 109 gm

Ballast 28 gm

Gross weight less helium 1121 gm

Free lift 112 gm

Launch site 172° 32'E, 43° 29'S

Launch time 31/03/66 2253 UT

Ascent rate

0 - 5,000 m 1.4 m/sec

5,000 - 10,000 m 1.6 m/sec

Float altitude 12,400 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	45.5
30°	29.0
80°	15.9
80°	Occulting angle

Flight duration 74 days

Flight duration 80 balloon days

Number of orbits 6

Position last heard 62858 (11/06/66)

Balloon days tracked 51

Remarks: This balloon had an intermittent transmitter which failed several times. In one case the transmitter did not operate for a period of 13 days.

Probable cause of failure: transmitter failure.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 19203 G 20206 V

Frequency 15.023 15.026 MHz

Method of leak test air pressure

Test results less than .1% per day.
Leak near equator repaired.

Surface winds 020 ° 2 m/sec

Cloud cover

Climb-out winds 1700 UT

0 - 5,000 m 270° 5 m/sec

5,000 - 10,000 m 250° 10 m/sec

10,000 m - altitude 230° 35 m/sec

Altitude 250° 35 m/sec

Mfr. balloon # Schjeldahl 7

Balloon mass 977 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 235 gm

Ballast 17 gm

Gross weight less helium 1229 gm

Free lift 123 gm

Flight duration 39 days

Flight duration 42 balloon days

Number of orbits 3

Position last heard 63129 (14/05/66)

Balloon days tracked 30

Remarks: Upper package was 19203 G, electronics temperature.

Launch site 172° 32'E, 43° 29'S

Launch time 05/04/66 1845 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 1.8 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data VVV

Sun angle--Code period (10^{-1} sec)

10°	33.5
30°	18.8
80°	10.4
80°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 21207 U

Frequency 15.027 MHz

Method of leak test air pressure

Test results less than .1%

Surface winds 250° 6 m/sec

Cloud cover

Climb-out winds 2300 UT

0 - 5,000 m 250° 18 m/sec

5,000 - 10,000 m 250° 30 m/sec

10,000 m - altitude 260° 30 m/sec

Altitude 270° 25 m/sec

Mfr. balloon # Schjeldahl 9

Balloon mass 988 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 130 gm

Ballast 111 gm

Gross weight less helium 1229 gm

Free lift 123 gm

Launch site 172° 32'E, 43° 29'S

Launch time 06/04/66 2135 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 1.8 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10°	45.4
30°	27.5
80°	14.6
80°	Occulting angle

Flight duration 17 days

Flight duration 18 balloon days

Number of orbits 1

Position last heard 56977 (24/04/66)

Balloon days tracked 17

Remarks: Sun sensor was open circuited for 2 hr immediately after launch but operated properly for the duration of the flight.

Balloon may have been damaged in a rough launch.

Balloon moved into the Antarctic night on 24/04/66.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 22203 R

Frequency 15.023 MHz

Method of leak test air pressure

Test results less than .1%

Surface winds 250° 6 m/sec

Cloud cover

Climb-out winds 2300 UT

0 - 5,000 m 250° 18 m/sec

5,000 - 10,000 m 250° 30 m/sec

10,000 m - altitude 260° 30 m/sec

Altitude 270° 25 m/sec

Mfr. balloon # Schjeldahl 10

Balloon mass 972 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 132 gm

Ballast 125 gm

Gross weight less helium 1229 gm

Free lift 123 gm

Launch site 172° 32'E, 43° 29'S

Launch time 06/04/66 2140 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 1.8 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	40.9
30°	23.6
80°	12.2
80°	Occulting angle

Flight duration 8 days

Flight duration 6 balloon days

Number of orbits 0

Position last heard 54332 (14/04/66)

Balloon days tracked 6

Remarks: This balloon had an extremely rough launch in gusty winds. The antenna struck a fence after release with no apparent damage.

Probable cause of failure: balloon leak.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 23206 F

Frequency 15.026 MHz

Method of leak test

Test results

Surface winds ° calm m/sec

Cloud cover

Climb-out winds 1700 UT

0 - 5,000 m 240° 10 m/sec

5,000 - 10,000 m 220° 28 m/sec

10,000 m - altitude 210° 25 m/sec

Altitude 220° 22 m/sec

Mfr. balloon # Raven 127

Balloon mass 967 gm

Balloon volume 4.19 m^3

Balloon diameter 2.0 m

Film thickness 1.5 mils

Electronics mass 133 gm

Ballast 60 gm

Gross weight less helium 1160 gm

Free lift gm

Launch site 172° 32'E, 43° 29'S

Launch time 10/04/66 1846 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 1.8 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10° 44.5

30° 26.5

80° 15.0

80° Occulting angle

Flight duration 51 days

Flight duration 54 balloon days

Number of orbits 3

Position last heard 64048 (31/05/66)

Balloon days tracked 38

Remarks: Balloon moved into Antarctic night on 3 occasions.

Probable cause of failure: balloon leak.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 24202 S

Frequency 15.022 MHz

Method of leak test air pressure

Test results less than .05%

Surface winds ° calm m/sec

Cloud cover clear

Climb-out winds 1700 UT

0 - 5,000 m 200° 5 m/sec

5,000 - 10,000 m 120° 5 m/sec

10,000 m - altitude 120° 6 m/sec

Altitude 100° 5 m/sec

Mfr. balloon # Schjeldahl 12

Balloon mass 978 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 108 gm

Ballast 143 gm

Gross weight less helium 1229 gm

Free lift 123 gm

Launch site 172° 32'E, 43° 29'S

Launch time 12/04/66 1845 UT

Ascent rate

0 - 5,000 m 1.4 m/sec

5,000 - 10,000 m 1.8 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	39.2
30°	22.0
80°	12.1
80°	Occulting angle

Flight duration 57 days

Flight duration 61 balloon days

Number of orbits 4

Position last heard 64245 (08/06/66)

Balloon days tracked 55

Remarks: Balloon heard on 09/07/66 by Lima station on 89th day, located near equator.

Probable cause of failure: transmitter failure.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 25209 A

Frequency 15.029 MHz

Method of leak test air pressure

Test results Balloon showed a gas loss of .25% per day in tests. Leak discovered & repaired, not tested further.

Mfr. balloon # Schjeldahl 11

Balloon mass 974 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 129 gm

Ballast 126 gm

Gross weight less helium 1229 gm

Free lift 123 gm

Launch site 172° 32'E, 43° 29'S

Launch time 14/04/66 1852 UT

Ascent rate

0 - 5,000 m 1.4 m/sec

5,000 - 10,000 m 1.8 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	37.0
30°	24.4
80°	14.2
80°	Occulting angle

Surface winds ° calm m/sec

Cloud cover

Climb-out winds 1700 UT

0 - 5,000 m 270° 3 m/sec

5,000 - 10,000 m 280° 5 m/sec

10,000 m - altitude 310° 12 m/sec

Altitude 310° 12 m/sec

Flight duration 30 days

Flight duration 32 balloon days

Number of orbits 2

Position last heard 63353 (14/05/66)

Balloon days tracked 22

Remarks: Leak repaired near balloon equator prior to flight.

Poor tracking due to high frequency -- close to Radio Peking.

Probable cause of failure: balloon leak

GHOST BALLOON FLIGHT SUMMARY

Balloon # 26204 K

Frequency 15.024 MHz

Method of leak test air pressure

Test results less than .15%

Surface winds 040° 7 m/sec

Cloud cover broken altostratus

Climb-out winds 1700 UT

0 - 5,000 m 270° 12 m/sec

5,000 - 10,000 m 250° 40 m/sec

10,000 m - altitude 250° 55 m/sec

Altitude 250° 50 m/sec

Mfr. balloon # Schjeldahl 1

Balloon mass 977 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 105 gm

Ballast 147 gm

Gross weight less helium 1229 gm

Free lift 123 gm

Flight duration 0 days

Flight duration balloon days

Number of orbits

Position last heard

Balloon days tracked

Remarks: No signals received at the Christchurch station from this balloon. It is assumed that it iced up and descended into the ocean.

Launch site 172° 32'E, 43° 29'S

Launch time 18/04/66 1845 UT

Ascent rate

0 - 5,000 m m/sec

5,000 - 10,000 m m/sec

Float altitude m

Radar

Computed

Calibration data

Sun angle--Code period (10^{-1} sec)

Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 27203 B

Frequency 15.023 MHz

Method of leak test air pressure

Test results lost .4% per day. Pinhole leak discovered 10° from equator & repaired. No further test.

Mfr. balloon # Schjeldahl 2

Balloon mass 958 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 105 gm

Ballast 166 gm

Gross weight less helium 1229 gm

Free lift 123 gm

Launch site 172° 32'E, 43° 29'S

Launch time 26/04/66 2143 UT

Ascent rate

0 - 5,000 m 1.4 m/sec

5,000 - 10,000 m 1.8 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

20° 22.5

30° 15.0

80° Occulting angle

Surface winds 210° 2 m/sec

Cloud cover

Climb-out winds 2300 UT

0 - 5,000 m 220° 8 m/sec

5,000 - 10,000 m 220° 12 m/sec

10,000 m - altitude 230° 12 m/sec

Altitude 230° 10 m/sec

Flight duration see remarks days

Flight duration balloon days

Number of orbits

Position last heard

Balloon days tracked 3

Remarks: This balloon had a defective transmitter which made it very difficult to read except when the balloon was very close. The balloon was heard on 11/06/66 on its 76th day in Djakarta.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 28203 X

Frequency 15.023 MHz

Method of leak test air pressure

Test results less than .05%

Surface winds ° m/sec

Cloud cover

Climb-out winds 2300 UT

0 - 5,000 m 360° 20 m/sec

5,000 - 10,000 m 340° 25 m/sec

10,000 m - altitude 340° 33 m/sec

Altitude 340° 33 m/sec

Mfr. balloon # Schjeldahl 3

Balloon mass 983 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 108 gm

Ballast 138 gm

Gross weight less helium 1229 gm

Free lift 123 gm

Flight duration 192 days

Flight duration 208 balloon days

Number of orbits 16

Position last heard 62344 (04/11/66)

Balloon days tracked 206

Remarks: Probable cause of failure: balloon leak.

Launch site 172° 32'E, 43° 29'S

Launch time 28/04/66 1857 UT

Ascent rate

0 - 5,000 m 1.4 m/sec

5,000 - 10,000 m 1.8 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	44.6
30°	27.4
80°	14.9
80°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 29204 Z

Frequency 15.024 MHz

Method of leak test air pressure

Test results less than .1%

Surface winds ° calm m/sec

Cloud cover clear

Climb-out winds 2300 UT

0 - 5,000 m 200° 4 m/sec

5,000 - 10,000 m 190° 10 m/sec

10,000 m - altitude 240° 10 m/sec

Altitude 240° 10 m/sec

Mfr. balloon # Schjeldahl 4

Balloon mass 977 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 107 gm

Ballast 145 gm

Gross weight less helium 1229 gm

Free lift 148 gm

Flight duration 31 days

Flight duration 33 balloon days

Number of orbits 2

Position last heard 63426 (03/06/66)

Balloon days tracked 33

Remarks:

Probable cause of failure: balloon leak.

Launch site 172° 32'E, 43° 29'S

Launch time 03/05/66 1841 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 1.9 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	40.4
30°	25.4
80°	14.5
80°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 30202 C

Frequency 15.022 MHz

Method of leak test air pressure

Test results lost .5% per day. Small hole discovered & repaired 2 ft above inflation fitting. Retested - less than .1% per day.

Mfr. balloon # Raven 129

Balloon mass 974 gm

Balloon volume 4.19 m^3

Balloon diameter 2.0 m

Film thickness 1.5 mils

Electronics mass 115 gm

Ballast 71 gm

Gross weight less helium 1160 gm

Free lift 128 gm

Launch site $172^\circ 32'$E, $43^\circ 29'$S

Launch time 08/05/66 1933 UT

Ascent rate

0 - 5,000 m 1.4 m/sec

5,000 - 10,000 m 1.8 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	26.4
30°	16.6
80°	9.2
80°	Occulting angle

Surface winds $^\circ$ calm m/sec

Cloud cover

Climb-out winds 1700 UT

0 - 5,000 m 300° 2 m/sec

5,000 - 10,000 m 270° 15 m/sec

10,000 m - altitude 270° 17 m/sec

Altitude 280° 17 m/sec

Flight duration 39 days

Flight duration 42 balloon days

Number of orbits 3

Position last heard ** (16/06/66)

Balloon days tracked 42

Remarks: This balloon was launched 3 min prior to 31206 D. The balloons remained within 200 km of each other for the first 14 days of flight.

** Last position with good data 51487 on (14/06/66).

Probable cause of failure: balloon leak.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 31206 D

Frequency 15.026 MHz

Method of leak test air pressure

Test results less than .1%

Surface winds ° m/sec

Cloud cover

Climb-out winds 1700 UT

0 5,000 m 300° 2 m/sec

5,000 - 10,000 m 270° 15 m/sec

10,000 m - altitude 270° 17 m/sec

Altitude 280° 17 m/sec

Mfr. balloon # Raven 131

Balloon mass 964 gm

Balloon volume 4.19 m^3

Balloon diameter 2.0 m

Film thickness 1.5 mils

Electronics mass 106 gm

Ballast 90 gm

Gross weight less helium 1160 gm

Free lift 128 gm

Flight duration 17 days

Flight duration 18 balloon days

Number of orbits 1

Position last heard 84734 (25/06/66)

Balloon days tracked 18

Remarks: See balloon 30202 C. Probable cause of failure: balloon leak.

Launch site 172° 32'E, 43° 29'S

Launch time 08/05/66 1936 UT

Ascent rate

0 - 5,000 m 1.4 m/sec

5,000 - 10,000 m 1.8 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10°	28.2
30°	17.6
80°	9.9
80°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 32506 DWRK

Frequency 15.026 MHz

Method of leak test helium lift

Test results less than .05%

Surface winds ° calm m/sec

Cloud cover

Climb-out winds 1700 UT

0 - 5,000 m 250° 6 m/sec

5,000 - 10,000 m

10,000 m - altitude

Altitude 250° 7 m/sec

Mfr. balloon # Schjeldahl 2-A

Balloon mass 890 gm

Balloon volume 1.95 m^3

Balloon diameter 1.54 m

Film thickness 2.5 mils

Electronics mass 132 gm

Ballast 128 gm

Gross weight less helium 1150 gm

Free lift 363 gm

Launch site 172° 32'E, 43° 29'S

Launch time 12/05/66 2043 UT

Ascent rate

0 - 5,000 m 2.5 m/sec

5,000 - 10,000 m m/sec

Float altitude 5735 m

Radar xxxx

Computed

Flight duration 5 days

Flight duration 5 balloon days

Number of orbits 0

Position last heard 63539 (17/05/66)

Balloon days tracked

Remarks: This balloon was wax treated. Total mass of wax was 9 gm. This 4 coder measured sun angle, air temperature, film strain, and electronics temperature. The stress-strain data and creep information are discussed in the body of the text. Electronics temperature varied from +2° C to +26° C.

This balloon was heard on 17/07/66 in Djakarta.

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	43.0
30°	25.5
86°	13.7
86°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 33504 P

Frequency 15.024 MHz

Method of leak test helium test

Test results less than .05%

Surface winds ° calm m/sec

Cloud cover

Climb-out winds 1700 UT

0 - 5,000 m 270° 9 m/sec

5,000 - 10,000 m

10,000 m - altitude

Altitude 270° 14 m/sec

Mfr. balloon # Schjeldahl 1-A

Balloon mass 890 gm

Balloon volume 1.95 m^3

Balloon diameter 1.54 m

Film thickness 2.5 mils

Electronics mass 120 gm

Ballast 57 gm

Gross weight less helium 1067 gm

Free lift 320 gm

Launch site 172° 32'E, 43° 29'S

Launch time 16/05/66 2025 UT

Ascent rate

0 - 5,000 m 3 m/sec

5,000 - 10,000 m m/sec

Float altitude 6200 m

Radar

Computed xxxx

Flight duration 3 days

Flight duration 3 balloon days

Number of orbits 0

Position last heard 61862 (19/05/66)

Balloon days tracked 3

Remarks: This balloon was wax treated and had 30% free lift. The balloon was girdled with 6 layers of glass filament tape around the equator to prevent burst.

Probable cause of failure: icing.

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	32.5
30°	19.2
83°	10.7
83°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 34206 J

Frequency 15.026 MHz

Method of leak test helium lift

Test results less than .05%

Mfr. balloon # Schjeldahl 18

Balloon mass 981 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 116 gm

Ballast 132 gm

Gross weight less helium 1229 gm

Free lift 172 gm

Launch site 172° 32'E, 43° 29'S

Launch time 25/05/66 0414 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10°	29.8
30°	18.9
80°	10.8

80° Occulting angle

Surface winds 210 ° 3 m/sec

Cloud cover overcast above, clear to east

Climb-out winds 0500 UT

0 - 5,000 m 180° 2 m/sec

5,000 - 10,000 m 290° 5 m/sec

10,000 m - altitude 270° 8 m/sec

Altitude 250° 10 m/sec

Flight duration 234 days

Flight duration 253 balloon days

Number of orbits 19

Position last heard 74932 (13/01/67)

Balloon days tracked 240

Remarks: Last reported good transmission on 13/01/67 on 234th day. Balloon was heard intermittently on 24/01/67 by the Huancayo Observatory, Peru. Failure may have been electronic.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 35203 R

Frequency 15.023 MHz

Method of leak test helium lift

Test results less than .04%

Mfr. balloon # Schjeldahl 19

Balloon mass 980 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 116 gm

Ballast 133 gm

Gross weight less helium 1229 gm

Free lift 172 gm

Launch site 172° 32'E, 43° 29'S

Launch time 25/05/66 0432 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	36.5
30°	20.8
80°	11.4
80°	Occulting angle

Surface winds 210 ° 3 m/sec

Cloud cover overcast above, clear to east

Climb-out winds 0500 UT

0 - 5,000 m 180° 2 m/sec

5,000 - 10,000 m 290° 5 m/sec

10,000 m - altitude 270° 8 m/sec

Altitude 250° 10 m/sec

Flight duration 25 days

Flight duration 27 balloon days

Number of orbits 2

Position last heard 64650 (13/06/66)

Balloon days tracked 9

Remarks: This balloon remained at high latitudes. Balloon was heard on 18/06/66 but no position obtained.

Balloon life may have been one month or more longer than recorded as it remained in the Antarctic night.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 36204 K

Frequency 15.024 MHz

Method of leak test helium lift

Test results less than .06%

Surface winds 210° 3 m/sec

Cloud cover overcast above, clear to east

Climb-out winds 0500 UT

0 - 5,000 m 180° 2 m/sec

5,000 - 10,000 m 290° 5 m/sec

10,000 m - altitude 270° 8 m/sec

Altitude 250° 10 m/sec

Mfr. balloon # Schjeldahl 20

Balloon mass 977 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 123 gm

Ballast 129 gm

Gross weight less helium 1229 gm

Free lift 172 gm

Flight duration 39 days

Flight duration ? balloon days

Number of orbits ?

Position last heard 75002 (09/06/66)

Balloon days tracked 8

Remarks: This balloon moved into the Antarctic night and was tracked intermittently. Last good data was on 09/06/66. Last data was on 02/07/66.

Launch site 172° 32'E, 43° 29'S

Launch time 25/05/66 0425 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	27.0
30°	15.7
80°	8.9
80°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 37202 W

Frequency 15.022 MHz

Method of leak test not tested

Test results

Surface winds 040° 5 m/sec

Cloud cover

Climb-out winds 1700 UT

0 - 5,000 m 270° 6 m/sec

5,000 - 10,000 m 210° 17 m/sec

10,000 m - altitude 210° 14 m/sec

Altitude 210° 11 m/sec

Mfr. balloon # Schjeldahl 17

Balloon mass 978 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 106 gm

Ballast 145 gm

Gross weight less helium 1229 gm

Free lift 172 gm

Launch site 172° 32'E, 43° 29'S

Launch time 26/05/66 1900 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

see remarks

Occulting angle

Flight duration see remarks days

Flight duration balloon days

Number of orbits

Position last heard

Balloon days tracked

Remarks: Transmitter on this balloon put out less than 10% normal power. It was heard weakly for 3 days at Christchurch and then not picked up again. The duration of flight is not known.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 38206 U

Frequency 15.026 MHz

Method of leak test not tested

Test results

Surface winds 040° 5 m/sec

Cloud cover

Climb-out winds 1700 UT

0 - 5,000 m 270° 6 m/sec

5,000 - 10,000 m 210° 17 m/sec

10,000 m - altitude 210° 14 m/sec

Altitude 210° 11 m/sec

Mfr. balloon # Schjeldahl 16

Balloon mass 970 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 116 gm

Ballast 143 gm

Gross weight less helium 1229 gm

Free lift 172 gm

Flight duration 5 days

Flight duration 5 balloon days

Number of orbits 0

Position last heard 63110 (01/06/66)

Balloon days tracked

Remarks:

Probable cause of failure: balloon leak (balloon was not tested).

Launch site 172° 32'E, 43° 29'S

Launch time 26/05/66 1902 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	31.5
30°	17.8
80°	9.6
80°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 39208 H

Frequency 15.028 MHz

Method of leak test air pressure

Test results less than .05%

Surface winds ° calm m/sec

Cloud cover clear

Climb-out winds 1700 UT

0 - 5.000 m 280° 18 m/sec

5,000 - 10,000 m 310° 40 m/sec

10,000 m - altitude 320° 46 m/sec

Altitude 320° 45 m/sec

Mfr. balloon # Schjeldahl 13

Balloon mass 982 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 116 gm

Ballast 131 gm

Gross weight less helium 1229 gm

Free lift 172 gm

Launch site 172° 32'E, 43° 29'S

Launch time 02/06/66 2002 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10°	28.4
30°	16.9
80°	9.6
80°	Occulting angle

Flight duration 85 days

Flight duration 91+ balloon days

Number of orbits 6+

Position last heard 65705 (21/08/66)

Balloon days tracked 50

Remarks: This balloon remained in the Antarctic night during much of July and August. Last good data on 21/08/66. Last data on 26/08/66.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 40204 B

Frequency 15.024 MHz

Method of leak test air pressure

Test results less than .05%

Mfr. balloon # Schjeldahl 15

Balloon mass 976 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 116 gm

Ballast 137 gm

Gross weight less helium 1229 gm

Free lift 172 gm

Launch site 172° 32'E, 43° 29'S

Launch time 06/06/66 0010 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10°	25.2
30°	16.0
80°	9.4
80°	Occulting angle

Surface winds 210 ° 4 m/sec

Cloud cover

Climb-out winds 2300 UT

0 - 5,000 m 240° 9 m/sec

5,000 - 10,000 m 250° 10 m/sec

10,000 m - altitude 250° 10 m/sec

Altitude 260° 10 m/sec

Flight duration 209 days

Flight duration 225 balloon days

Number of orbits 16

Position last heard 84765 (31/12/66)

Balloon days tracked 216

Remarks: Last report with good data transmission on 31/12/66. Balloon heard briefly on 13/01/67 by Melbourne and on 20/01/67 by Lima. Failure may have been electronic.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 41204 W

Frequency 15.024 MHz

Method of leak test air pressure

Test results less than .05%

Surface winds ° calm m/sec

Cloud cover

Climb-out winds 1700 UT

0 - 5,000 m 180° 9 m/sec

5,000 - 10,000 m 220° 18 m/sec

10,000 m - altitude 210° 22 m/sec

Altitude 210° 22 m/sec

Mfr. balloon # Schjeldahl 14

Balloon mass 982 gm

Balloon volume 4.44 m^3

Balloon diameter 2.04 m

Film thickness 1.5 mils

Electronics mass 110 gm

Ballast 137 gm

Gross weight less helium 1229 gm

Free lift 172 gm

Flight duration 89 days

Flight duration 96 balloon days

Number of orbits 7

Position last heard 52850 (12/09/66)

Balloon days tracked 80

Remarks: Probable cause of failure: balloon leak.

Launch site 172° 32'E, 43° 29'S

Launch time 15/06/66 2142 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	19.6
30°	12.5
80°	7.4
80°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 42506 P

Frequency 15.027 MHz

Method of leak test tent test

Test results no leaks found

Surface winds ° 5 m/sec

Cloud cover see remarks

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 17

Balloon mass 875 gm

Balloon volume 1.86 m^3

Balloon diameter 1.52 m

Film thickness 2.5 mils

Electronics mass 114 gm

Ballast 115 gm

Gross weight less helium 1104 gm

Free lift 275 gm

Launch site 172° 32'E, 43° 29'S

Launch time 28/06/66 2110 UT

Ascent rate

0 - 5,000 m see remarks m/sec

5,000 - 10,000 m m/sec

Float altitude m

Radar

Computed

Calibration data

Sun angle--Code period (10^{-1} sec)

Occulting angle

Flight duration 0 days

Flight duration 0 balloon days

Number of orbits 0

Position last heard

Balloon days tracked

Remarks: This balloon was waxed and flown in a heavy overcast with tops at 5000 m. The signals were never received at the station from the balloon.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 43502 N

Frequency 15.023 MHz

Method of leak test tent test

Test results no leaks found

Surface winds ° calm m/sec

Cloud cover see remarks

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 16

Balloon mass 877 gm

Balloon volume 1.86 m^3

Balloon diameter 1.52 m

Film thickness 2.5 mils

Electronics mass 140 gm

Ballast 87 gm

Gross weight less helium 1104 gm

Free lift 276 gm

Launch site 172° 32'E, 43° 29'S

Launch time 29/06/66 1923 UT

Ascent rate

0 - 5,000 m 3 m/sec

5,000 - 10,000 m m/sec

Float altitude 5600 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	32.0
30°	19.6
83°	11.1
83°	Occulting angle

Flight duration 2 days

Flight duration 2 balloon days

Number of orbits 0

Position last heard 62872 (01/07/66)

Balloon days tracked

Remarks: Broken altostratus at 3 km; scattered cirrus at 10 km.

Probable cause of failure: balloon icing.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 44205 N

Frequency 15.025 MHz

Method of leak test tent test

Test results no leaks found

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Raven 22

Balloon mass 956 gm

Balloon volume 4.19 m^3

Balloon diameter 2.0 m

Film thickness 1.5 mils

Electronics mass 114 gm

Ballast 90 gm

Gross weight less helium 1160 gm

Free lift 162 gm

Flight duration 3 days

Flight duration 3 balloon days

Number of orbits 0

Position last heard 63312 (17/07/66)

Balloon days tracked

Remarks: Techniques used at this time in the tent test were not satisfactory for uncovering leaks.

Launch site 172° 32'E, 43° 29'S

Launch time 14/07/66 2045 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	28.0
30°	15.4
80°	9.6
80°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 45202 C

Frequency 15.022 MHz

Method of leak test tent test

Test results no leaks

uncovered

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Raven 16

Balloon mass 959 gm

Balloon volume 4.19 m^3

Balloon diameter 2.0 m

Film thickness 1.5 mils

Electronics mass 113 gm

Ballast 88 gm

Gross weight less helium 1160 gm

Free lift 162 gm

Launch site 172° 32'E, 43° 29'S

Launch time 25/07/66 2052 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10° 20.0

30° 12.7

80° 7.6

80° Occulting angle

Flight duration 4 days

Flight duration 4 balloon days

Number of orbits 0

Position last heard 63006 (29/07/66)

Balloon days tracked

Remarks: The tent test technique as used at this time was not satisfactory for detecting leaks. It is apparent that this balloon was not leak free.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 46505 P

Frequency 15.025 MHz

Method of leak test tent test

Test results no leaks detected

Mfr. balloon # Schjeldahl 14

Balloon mass 879 gm

Balloon volume 1.86 m^3

Balloon diameter 1.52 m

Film thickness 2.5 mils

Electronics mass 116 gm

Ballast 109 gm

Gross weight less helium 1104 gm

Free lift 276 gm

Launch site 172° 32'E, 43° 29'S

Launch time 31/07/66 2335 UT

Ascent rate

0 - 5,000 m 3 m/sec

5,000 - 10,000 m m/sec

Float altitude 5550 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	21.2
30°	13.3
83°	7.8
83°	Occulting angle

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Flight duration 9 days

Flight duration 9 balloon days

Number of orbits 0

Position last heard 63450 (06/08/66)

Balloon days tracked 5

Remarks: An error in computation resulted in the free lift at launch of 359 gm -- 35%. Balloon was wax treated and equipped with a special harness to insure against damage to transmitter from turbulence.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 47205 A

Frequency 15.025 MHz

Method of leak test tent test

Test results two leaks detected and repaired

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Raven 21

Balloon mass 963 gm

Balloon volume 4.19 m^3

Balloon diameter 2.0 m

Film thickness 1.5 mils

Electronics mass 167 gm

Ballast 30 gm

Gross weight less helium 1160 gm

Free lift 162 gm

Flight duration 23 days

Flight duration 24 balloon days

Number of orbits 1

Position last heard 71955 (31/08/66)

Balloon days tracked 23

Remarks: Probable cause of failure: balloon leak

Launch site 172° 32'E, 43° 29'S

Launch time 09/08/66 2121 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	21.0
30°	14.1
80°	9.6
80°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 48207 M

Frequency 15.027 MHz

Method of leak test tent test

Test results no leaks found

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Raven 15

Balloon mass 964 gm

Balloon volume 4.19 m^3

Balloon diameter 2.0 m

Film thickness 1.5 mils

Electronics mass 110 gm

Ballast 86 gm

Gross weight less helium 1160 gm

Free lift 162 gm

Flight duration 20+ days

Flight duration 21+ balloon days

Number of orbits 1

Position last heard

Balloon days tracked 5

Remarks: Transmission was intermittent and erratic. Electronics apparently failed on the 20th day.

Launch site 172° 32'E, 43° 29'S

Launch time 11/08/66 2100 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10°	30.2
30°	19.9
80°	11.8
80°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 49208 R

Frequency 15.028 MHz

Method of leak test see remarks

Test results 15 holes found and repaired

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Raven 23

Balloon mass 960 gm

Balloon volume 4.19 m^3

Balloon diameter 2.0 m

Film thickness 1.5 mils

Electronics mass 110 gm

Ballast 90 gm

Gross weight less helium 1160 gm

Free lift 162 gm

Launch site 172° 32'E, 43° 29'S

Launch time 02/09/66 2137 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	34.2
30°	23.6
80°	14.9
80°	Occulting angle

Flight duration 133 days

Flight duration 143 balloon days

Number of orbits 10

Position last heard 82555 (12/01/67)

Balloon days tracked 121

Remarks: Leak test by complete surface inspection with halogen detector.

This balloon had one crack 1/4" long on one gore as well as 14 small pinholes which were detected using the halogen detector. Because of the extensive surface testing, the tent test was not used prior to flight.

Transmitter keyed improperly on first flight day.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 50201 D

Frequency 15.021 MHz

Method of leak test tent test

Test results 3 leaks detected and repaired

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Raven 12

Balloon mass 965 gm

Balloon volume 4.19 m^3

Balloon diameter 2.0 m

Film thickness 1.5 mils

Electronics mass 118 gm

Ballast 77 gm

Gross weight less helium 1160 gm

Free lift 162 gm

Flight duration 148 days

Flight duration 157 balloon days

Number of orbits 9

Position last heard 65945 (01/02/67)

Balloon days tracked 150

Remarks:

Probable cause of failure: balloon leak.

Launch site 172° 32'E, 43° 29'S

Launch time 07/09/66 2129 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10°	29.1
30°	18.9
80°	11.1

80° Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 51206 P

Frequency 15.026 MHz

Method of leak test tent test

Test results 1 pinhole leak detected and repaired

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5 000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Raven 18

Balloon mass 955 gm

Balloon volume 4.19 m^3

Balloon diameter 2.0 m

Film thickness 1.5 mils

Electronics mass 115 gm

Ballast 90 gm

Gross weight less helium 1160 gm

Free lift 162 gm

Flight duration 67 days

Flight duration 72 balloon days

Number of orbits 5

Position last heard 52544 (29/11/66)

Balloon days tracked 70

Remarks:

Probable cause of failure: balloon leak.

Launch site 172° 32'E, 43° 29'S

Launch time 24/09/66 2025 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10°	31.3
30°	21.1
80°	12.8
80°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 52207 W

Frequency 15.027 MHz

Method of leak test tent test

Test results no leaks found

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Raven 19

Balloon mass 961 gm

Balloon volume 4.19 m^3

Balloon diameter 2.0 m

Film thickness 1.5 mils

Electronics mass 152 gm

Ballast 47 gm

Gross weight less helium 1160 gm

Free lift 162 gm

Flight duration 16 days

Flight duration 17 balloon days

Number of orbits 1

Position last heard 67330 (29/11/66)

Balloon days tracked 17

Remarks:

Probable cause of failure: balloon leak.

Launch site $172^\circ 32'$E, $43^\circ 29'$S

Launch time 10/10/66 2020 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	22.5
30°	14.3
80°	7.8
80°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 53507 Z

Frequency 15.027 MHz

Method of leak test tent test

Test results no leaks found

Mfr. balloon # Schjeldahl 5

Balloon mass 874 gm

Balloon volume 1.853 m^3

Balloon diameter 1.524 m

Film thickness 2.5 mils

Electronics mass 118 gm

Ballast 112 gm

Gross weight less helium 1104 gm

Free lift 442 gm

Launch site 172° 32'E, 43° 29'S

Launch time 11/10/66 2004 UT

Ascent rate

0 - 5,000 m 3.1 m/sec

5,000 - 10,000 m m/sec

Float altitude 5585 m

Radar xxxx

Computed

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	22.6
30°	14.3
83°	7.6
83°	Occulting angle

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Flight duration 14 days

Flight duration 14 balloon days

Number of orbits 0

Position last heard (24/10/66)

Balloon days tracked 5

Remarks: This balloon was wax treated and was reinforced with three horizontal bands of GT-12 tape across the equator section. Balloon reached the Andes but did not cross.

Probable cause of failure: either icing or contact with the Andes.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 54503 L

Frequency 15.023 MHz

Method of leak test tent test

Test results 1 pinhole detected and repaired

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 6

Balloon mass 886 gm

Balloon volume 1.853 m^3

Balloon diameter 1.524 m

Film thickness 2.5 mils

Electronics mass 118 gm

Ballast 100 gm

Gross weight less helium 1104 gm

Free lift 442 gm

Launch site 172° 32'E, 43° 29'S

Launch time 11/10/66 2004 UT

Ascent rate

0 - 5,000 m 3.1 m/sec

5,000 - 10,000 m m/sec

Float altitude 5585 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	27.6
30°	16.8
83°	8.9
83°	Occulting angle

Flight duration 11 days

Flight duration 11 balloon days

Number of orbits 0

Position last heard 53375 (21/10/66)

Balloon days tracked

Remarks: This balloon was coated with wax and reinforced with GT-12 tape placed in planes along the equator and at 45°-offsets from the equator. The balloon reached South America.

Probable cause of failure: icing or contact with the Andes.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 55201 M

Frequency 15.021 MHz

Method of leak test tent test

Test results 2 pinhole leaks found & repaired. Large hole burned in balloon fabric during pinhole repair was also repaired.

Mfr. balloon # Raven 20

Balloon mass 962 gm

Balloon volume 4.19 m^3

Balloon diameter 2.0 m

Film thickness 1.5 mils

Electronics mass 147 gm

Ballast 51 gm

Gross weight less helium 1160 gm

Free lift 162 gm

Launch site 172° 32'E, 43° 29'S

Launch time 13/10/66 2040 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	30.5
30°	19.4
80°	12.3
80°	Occulting angle

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Flight duration 134 days

Flight duration 143 balloon days

Number of orbits 9 ?

Position last heard 63560 (23/02/67)

Balloon days tracked 68

Remarks: This balloon had a history of intermittent transmitter operation.

Probable cause of failure: electronics failure.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 56034 L 56038 V

Frequency 15.034 15.028 MHz

Method of leak test not tested

Test results

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 4

Balloon mass 6556 gm

Balloon volume 158 m^3

Balloon diameter 6.70 m

Film thickness 1 mils

Electronics mass 288 gm

Ballast 96 gm

Gross weight less helium 6940 gm

Free lift 1249 gm

Launch site 172° 32'E, 43° 29'S

Launch time 26/10/66 1730 UT

Ascent rate

0 - 10,000 m 3.8 m/sec

10,000 - 24,000 m 3.4 m/sec

Float altitude 24,000 m

Radar

Computed xxxx

Calibration data VVV

Sun angle--Code period (10^{-1} sec)

10°	44.7
30°	30.1
68°	18.4
68°	Occulting angle

Flight duration 1 days

Flight duration 1 balloon days

Number of orbits 0

Position last heard

Balloon days tracked 1

Remarks: A separate transmitter was flown to check on electronics temperature at 30 mb. The electronics operated at 17°C with only minor fluctuations during the day. The balloon failed on the first night.

Probable cause of failure: large hole or rip introduced either in fabrication, handling, or during the high speed ascent.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 57200 0

Frequency 15.020 MHz

Method of leak test tent test

Test results no leaks found

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Raven 6

Balloon mass 978 gm

Balloon volume 4.19 m^3

Balloon diameter 2.0 m

Film thickness 1.5 mils

Electronics mass 114 gm

Ballast 68 gm

Gross weight less helium 1160 gm

Free lift 162 gm

Flight duration 67 days

Flight duration 71 balloon days

Number of orbits 4

Position last heard 62562 (05/01/67)

Balloon days tracked 69

Remarks:

Probable cause of failure: balloon leak.

Launch site 172° 32'E, 43° 29'S

Launch time 31/10/66 1652 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	30.2
30°	20.2
80°	11.6
80°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 58207 G

Frequency 15.027 MHz

Method of leak test tent test

Test results 1 pinhole leak detected and repaired

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Raven 9

Balloon mass 978 gm

Balloon volume 4.19 m^3

Balloon diameter 2.0 m

Film thickness 1.5 mils

Electronics mass 113 gm

Ballast 69 gm

Gross weight less helium 1160 gm

Free lift 162 gm

Flight duration 106 days

Flight duration 113 balloon days

Number of orbits 7

Position last heard 54245 (23/02/67)

Balloon days tracked 113

Remarks:

Probable cause of failure: balloon leak.

Launch site 172° 32'E, 43° 29'S

Launch time 09/11/66 1935 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	31.0
30°	20.4
80°	11.4
80°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 59207 ED

Frequency 15.027 MHz

Method of leak test not tested

Test results

Mfr. balloon # Schjeldahl 18

Balloon mass 1422 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 2.0 mils

Electronics mass 200 gm

Ballast 58 gm

Gross weight less helium 1680 gm

Free lift 300 gm

Launch site 166° 7'E, 77° 8'S

Launch time 13/11/66 0734 UT

Ascent rate

0 - 5,000 m 1.6 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
0°	33.5
30°	15.1
80°	6.6
80°	Occulting angle

Surface winds ° 5 m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Flight duration 12 days

Flight duration 15 balloon days

Number of orbits 3

Position last heard 57830 (24/11/66)

Balloon days tracked 15

Remarks: Balloon equipped with solar cell side panels for low sun angle transmission.

Probable cause of failure: balloon damage during cold inflation or windy launch.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 60203 TA

Frequency 15.023 MHz

Method of leak test not tested

Test results

Mfr. balloon # Schjeldahl 19

Balloon mass 1397 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 2.0 mils

Electronics mass 200 gm

Ballast 83 gm

Gross weight less helium 1680 gm

Free lift 300 gm

Launch site 166°7'E, 77°8'S

Launch time 14/11/66 2225 UT

Ascent rate

0 - 5,000 m 1.6 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

0°	41.0
30°	23.0
80°	11.4
30°	Occulting angle

Surface winds ° 4 m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Flight duration see remarks days

Flight duration balloon days

Number of orbits

Position last heard

Balloon days tracked

Remarks: Balloon equipped with solar cell side panels for low sun angle transmission.

It has remained at high latitudes during most of its life. On its 206th day (06/06/67) it was located at 56152. It then returned into the Antarctic night and reappeared momentarily on the 209th day (09/06/67).

GHOST BALLOON FLIGHT SUMMARY

Balloon # 61209 TR

Frequency 15.030 MHz

Method of leak test not tested

Test results

Surface winds ° 3 m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 2

Balloon mass 1410 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 2.0 mils

Electronics mass 200 gm

Ballast 70 gm

Gross weight less helium 1680 gm

Free lift 300 gm

Launch site 166°7'E, 77°8'S

Launch time 17/11/66 0925 UT

Ascent rate

0 - 5,000 m 1.6 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	32.4
30°	18.5
80°	8.2
80°	Occulting angle

Flight duration 89 days

Flight duration 93 balloon days

Number of orbits 4

Position last heard 74167 (13/02/67)

Balloon days tracked 82

Remarks: This balloon was not equipped with solar cell side panels.

Probable cause of failure: balloon leak introduced in fabrication, handling, or cold temperature inflation.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 62207 TN

Frequency 15.027 MHz

Method of leak test not tested

Test results

Mfr. balloon # Schjeldahl 1

Balloon mass 1381 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 2.0 mils

Electronics mass 223 gm

Ballast 76 gm

Gross weight less helium 1680 gm

Free lift 300 gm

Launch site 166°7'E, 77°8'S

Launch time 17/11/66 1025 UT

Ascent rate

0 - 5,000 m 1.6 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

0°	38.0	
10°	25.5	
30°	14.5	
80°	6.1	Occulting angle

Surface winds ° 4 m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Flight duration 21 days

Flight duration 24 balloon days

Number of orbits 3

Position last heard 57660 (07/12/66)

Balloon days tracked 24

Remarks: This balloon was equipped with solar cell side panels.

Probable cause of failure: balloon leak introduced either in fabrication, handling, cold weather inflation, or gusty launch.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 63203 L

Frequency 15.023 MHz

Method of leak test tent test

Test results no leaks detected

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Raven 5

Balloon mass 963 gm

Balloon volume 4.19 m^3

Balloon diameter 2.0 m

Film thickness 1.5 mils

Electronics mass 118 gm

Ballast 79 gm

Gross weight less helium 1160 gm

Free lift 162 gm

Flight duration 58 days

Flight duration 61 balloon days

Number of orbits 3

Position last heard 64532 (25/01/67)

Balloon days tracked 58

Remarks:

Probable cause of failure: balloon leak.

Launch site 172° 32'E, 43° 29'S

Launch time 27/11/66 2030 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	22.3
30°	14.6
80°	8.1
80°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 64034 N

Frequency 15.024 MHz

Method of leak test wading pool

Test results no leaks found

Surface winds ° calm m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 2

Balloon mass 6584 gm

Balloon volume 158 m^3

Balloon diameter 6.70 m

Film thickness 1 mils

Electronics mass 119 gm

Ballast 237 gm

Gross weight less helium 6940 gm

Free lift 1249 gm

Launch site 172° 32'E, 43° 29'S

Launch time 15/12/66 1645 UT

Ascent rate

0 -10,000 m 2.0 m/sec

10,000 - 24,000 m 2.5 m/sec

Float altitude 24,000 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	28.8
30°	16.6
66°	9.9
66°	Occulting angle

Flight duration 61 days

Flight duration 59 balloon days

Number of orbits -2

Position last heard 57160 (14/02/67)

Balloon days tracked 49

Remarks: This balloon was leak tested in the Canterbury Court Building, the largest building in Christchurch. Although it tested leak free, it was roughly handled during deflation.

The balloon carried 600 gm dry ice to reduce rate of rise.

Probable cause of failure: balloon leak.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 65505 A

Frequency 15.025 MHz

Method of leak test tent test

Test results no leaks detected

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5 000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 7

Balloon mass 887 gm

Balloon volume 1.853 m^3

Balloon diameter 1.524 m

Film thickness 2.5 mils

Electronics mass 116 gm

Ballast 101 gm

Gross weight less helium 1104 gm

Free lift 442 gm

Flight duration 4 days

Flight duration 4 balloon days

Number of orbits 0

Position last heard 54575 (19/12/66)

Balloon days tracked 3

Remarks: This balloon was reinforced and coated with a silicone wax.

Probable cause of failure: icing.

Launch site 172° 32'E, 43° 29'S

Launch time 15/12/66 1721 UT

Ascent rate

0 - 5,000 m 3 m/sec

5,000 - 10,000 m m/sec

Float altitude 5550 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	30.0
30°	18.6
83°	10.2
83°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 66502 H

Frequency 15.022 MHz

Method of leak test tent test

Test results no leaks detected

Mfr. balloon # Schjeldahl 9

Balloon mass 888 gm

Balloon volume 1.853 m^3

Balloon diameter 1.524 m

Film thickness 2.5 mils

Electronics mass 120 gm

Ballast 96 gm

Gross weight less helium 1104 gm

Free lift 442 gm

Launch site 172° 32'E, 43° 29'S

Launch time 15/12/66 1724 UT

Ascent rate

0 - 5,000 m 3 m/sec

5,000 - 10,000 m m/sec

Float altitude 5550 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10° 31.5

30° 20.4

83° 10.6

83° Occulting angle

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Flight duration 1 days

Flight duration 1 balloon days

Number of orbits 0

Position last heard 74778 (16/12/66)

Balloon days tracked

Remarks: This balloon was prepared in identical fashion to 65505A, except that a different silicone wax was used as a water repellent.

Probable cause of failure: icing.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 67306 U

Frequency 15.026 MHz

Method of leak test tent test

Test results no leaks detected

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 13

Balloon mass 1530 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 2.0 mils

Electronics mass 117 gm

Ballast 733 gm

Gross weight less helium 2380 gm

Free lift 300 gm

Launch site 172° 32'E, 43° 29'S

Launch time 15/01/67 0050 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 9,000 m 1.8 m/sec

Float altitude 9500 m

Radar xxxx

Computed

Calibration data

Sun angle--Code period (10^{-1} sec)

10°	26.4
30°	16.9
80°	9.2
80°	Occulting angle

Flight duration 11 days

Flight duration 11 balloon days

Number of orbits 0

Position last heard 84765 (25/01/67)

Balloon days tracked 11

Remarks: This balloon was a uvinol coated balloon (for ultraviolet resistance) designed to fly at 200 mb. It was ballasted for 300 mb flight.

Probable cause of failure: icing.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 68300 W

Frequency 15.020 MHz

Method of leak test tent test

Test results no leaks detected

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 21

Balloon mass 1503 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 2.0 mils

Electronics mass 124 gm

Ballast 753 gm

Gross weight less helium 2380 gm

Free lift 300 gm

Launch site 172° 32'E, 43° 29'S

Launch time 15/01/67 0313 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 9,000 m 1.8 m/sec

Float altitude 9200 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10° 23.4

30° 14.4

80° 7.6

80° Occulting angle

Flight duration 5 days

Flight duration 5 balloon days

Number of orbits 0

Position last heard 64648 (19/01/67)

Balloon days tracked 5

Remarks: This was a uvinol coated balloon designed for flight at 200 mb which was ballasted for flight at 300 mb.

Probable cause of failure: icing.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 69206 H

Frequency 15.026 MHz

Method of leak test not tested

Test results

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 14

Balloon mass 1474 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 2.0 mils

Electronics mass 121 gm

Ballast 85 gm

Gross weight less helium 1680 gm

Free lift 300 gm

Launch site 172° 32'E, 43° 29'S

Launch time 15/01/67 0350 UT

Ascent rate

0 - 5,000 m 1.6 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10°	24 2
30°	16.4
80°	9.5
80°	Occulting angle

Flight duration 6 days

Flight duration 6 balloon days

Number of orbits 0

Position last heard 63301 (21/01/67)

Balloon days tracked 6

Remarks: This was a uvinol coated balloon which was not tested. Subsequent tests on similar balloons indicated that the uvinol coating had not set prior to packing. It is assumed that this balloon which was carefully tested at the factory developed an imperfection during unpacking.

Probable cause of failure: balloon leak.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 70201 K

Frequency 15.021 MHz

Method of leak test not tested

Test results

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 20

Balloon mass 1453 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 2.0 mils

Electronics mass 157 gm

Ballast 70 gm

Gross weight less helium 1680 gm

Free lift 300 gm

Flight duration see remarks days

Flight duration balloon days

Number of orbits

Position last heard

Balloon days tracked

Remarks: Uvinol coated balloon. This balloon was still flying as of 08/06/67 on its 142nd day.

Launch site 172° 32'E, 43° 29'S

Launch time 17/01/67 2057 UT

Ascent rate

0 - 5,000 m 1.6 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	30.2
30°	20.6
80°	12.0
80°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 71207 X

Frequency 15.027 MHz

Method of leak test not tested

Test results

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 17

Balloon mass 1420 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 2.0 mils

Electronics mass 133 gm

Ballast 127 gm

Gross weight less helium 1680 gm

Free lift 300 gm

Flight duration 17 days

Flight duration 18 balloon days

Number of orbits 1

Position last heard 85332 (03/02/67)

Balloon days tracked 18

Remarks:

Probable cause of failure: balloon leak.

Launch site 172° 32'E, 43° 29'S

Launch time 18/01/67 2043 UT

Ascent rate

0 - 5,000 m 1.6 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	26.0
30°	17.1
80°	9.7
80°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 72207 C

Frequency 15.027 MHz

Method of leak test not tested

Test results

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 23

Balloon mass 1461 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 2.0 mils

Electronics mass 157 gm

Ballast 72 gm

Gross weight less helium 1680 gm

Free lift 300 gm

Launch site 172° 32'E, 43° 29'S

Launch time 17/01/67 2108 UT

Ascent rate

0 - 5,000 m 1.6 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10°	34.2
30°	21.8
80°	11.5
80°	Occulting angle

Flight duration 7 days

Flight duration 7 balloon days

Number of orbits 0

Position last heard 54872 (24/01/67)

Balloon days tracked 7

Remarks: It is believed that this uvinol coated balloon was packed before the surface treatment had hardened. The balloon may have been damaged in unpacking.

Probable cause of failure: balloon leak.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 73202 P

Frequency 15.022 MHz

Method of leak test not tested

Test results

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 15

Balloon mass 1467 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 2 mils

Electronics mass 149 gm

Ballast 64 gm

Gross weight less helium 1680 gm

Free lift 300 gm

Launch site 172° 32'E, 43° 29'S

Launch time 17/01/67 2128 UT

Ascent rate

0 - 5,000 m 1.6 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	25.0
30°	16.7
80°	9.3
80°	Occulting angle

Flight duration 4 days

Flight duration 4 balloon days

Number of orbits 0

Position last heard (20/01/67)

Balloon days tracked 4

Remarks: It is believed that this uvinol coated balloon was packed before the surface treatment had hardened. The balloon may have been damaged in unpacking.

Probable cause of failure: balloon leak.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 74038 F

Frequency 15.028 MHz

Method of leak test not tested

Test results

Surface winds ° calm m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 1

Balloon mass 6640 gm

Balloon volume 158 m^3

Balloon diameter 6.7 m

Film thickness 1 mils

Electronics mass 125 gm

Ballast 175 gm

Gross weight less helium 6940 gm

Free lift 1249 gm

Launch site 172° 32'E, 43° 29'S

Launch time 18/01/67 0945 UT

Ascent rate

0- 10,000 m 2.0 m/sec

10,000 - 24,000 m 2.5 m/sec

Float altitude 24,000 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	26.0
30°	17.2
66°	10.5
66°	Occulting angle

Flight duration 1 days

Flight duration 1 balloon days

Number of orbits 0

Position last heard 74556 (19/01/67)

Balloon days tracked 1

Remarks: This balloon was not tested. The balloon carried 600 gm dry ice to reduce its ascent rate.

Probable cause of failure: large hole or tear in balloon.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 75030 V

Frequency 15.030 MHz

Method of leak test not tested

Test results

Surface winds ° calm m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 3

Balloon mass 6297 gm

Balloon volume 158 m^3

Balloon diameter 6.7 m

Film thickness 1 mils

Electronics mass 149 gm

Ballast 494 gm

Gross weight less helium 6940 gm

Free lift 1249 gm

Flight duration 67 days

Flight duration 67 balloon days

Number of orbits

Position last heard 75422 (27/03/67)

Balloon days tracked 60

Remarks: The balloon carried 600 gm dry ice to reduce ascent rate.

Probable cause of failure: balloon leak.

Launch site 172° 32'E, 43° 29'S

Launch time 19/01/67 0935 UT

Ascent rate

0- 10,000 m 2.0 m/sec

10,000 - 24,000 m 2.5 m/sec

Float altitude 24,000 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	19.6
30°	12.8
66°	7.9
66°	Occulting angle

GHOST BALLOON FLIGHT SUMMARY

Balloon # 76034 Z

Frequency 15.024 MHz

Method of leak test not tested

Test results

Surface winds ° calm m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 5

Balloon mass 6042 gm

Balloon volume 158 m^3

Balloon diameter 6.7 m

Film thickness 1 mils

Electronics mass 178 gm

Ballast 720 gm

Gross weight less helium 6940 gm

Free lift 1249 gm

Launch site 172° 32'E, 43° 29'S

Launch time 19/01/67 0930 UT

Ascent rate

0 -10,000 m 2.0 m/sec

10,000 - 24,000 m 2.5 m/sec

Float altitude 24,000 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	24.2
30°	15.0
66°	8.6
66°	Occulting angle

Flight duration 18 days

Flight duration 18 balloon days

Number of orbits 0

Position last heard (06/02/67)

Balloon days tracked 15

Remarks: Balloon was launched with 600 gm dry ice to reduce ascent rate.

Probable cause of failure: balloon leak.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 77035 A

Frequency 15.025 MHz

Method of leak test not tested

Test results

Surface winds ° calm m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 6

Balloon mass 6326 gm

Balloon volume 158 m^3

Balloon diameter 6.7 m

Film thickness 1 mils

Electronics mass 151 gm

Ballast 463 gm

Gross weight less helium 6940 gm

Free lift 1249 gm

Launch site 172° 32'E, 43° 29'S

Launch time 20/01/67 0755 UT

Ascent rate

0- 10,000 m 2.0 m/sec

10,000 - 24,000 m 2.5 m/sec

Float altitude 24,000 m

Radar

Computed xxxx

Calibration data -- not available.

Sun angle--Code period (10^{-1} sec)

Occulting angle

Flight duration 1 days

Flight duration 1 balloon days

Number of orbits 0

Position last heard 74666 (21/01/67)

Balloon days tracked

Remarks: The balloon carried 600 gm dry ice to reduce ascent rate.

Probable cause of failure: balloon leak.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 78201 B

Frequency 15.021 MHz

Method of leak test not tested

Test results

Mfr. balloon # Schjeldahl 24

Balloon mass 1472 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 2 mils

Electronics mass 150 gm

Ballast 58 gm

Gross weight less helium 1680 gm

Free lift 300 gm

Launch site 172° 32'E, 43° 29'S

Launch time 05/02/67 2112 UT

Ascent rate

0 - 5,000 m 1.6 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10°	27.0
30°	18.5
80°	11.2
80°	Occulting angle

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Flight duration 2 days

Flight duration 2 balloon days

Number of orbits 0

Position last heard

Balloon days tracked 2

Remarks: It is believed that this uvinol coated balloon was packed before the surface treatment had hardened.

Probable cause of failure: balloon leak.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 79202 R

Frequency 15.022 MHz

Method of leak test tent test

Test results no leaks detected

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 16

Balloon mass 1440 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 2 mils

Electronics mass 127 gm

Ballast 113 gm

Gross weight less helium 1680 gm

Free lift 300 gm

Launch site 172° 32'E, 43° 29'S

Launch time 15/02/67 2205 UT

Ascent rate

0 - 5,000 m 1.6 m/sec

5,000 - 10,000 m 2.0 m/sec

Float altitude 11,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	26.2
30°	17.3
80°	9.5
80°	Occulting angle

Flight duration see remarks days

Flight duration balloon days

Number of orbits

Position last heard

Balloon days tracked

Remarks: Balloon last heard on 26/05/67 on its 100th day. Believed to be presently in the Antarctic night and still flying.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 80303 DMHU

Frequency 15.023 MHz

Method of leak test tent test

Test results no leaks discovered

Surface winds ° m/sec

Cloud cover broken altocumulus

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude 270° 25 m/sec

Mfr. balloon # Schjeldahl 4

Balloon mass 2108 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 3.0 mils

Electronics mass 169 gm

Ballast 103 gm

Gross weight less helium 2380 gm

Free lift 300 gm

Launch site 172° 32'E, 43° 29'S

Launch time 20/02/67 2210 UT

Ascent rate

0 - 5,000 m 1.4 m/sec

5,000 - 9,000 m 1.6 m/sec

Float altitude 9160 m

Radar

Computed xxxx

Calibration data HHH

Sun angle--Code period (10^{-1} sec)

10°	22.6
30°	14.9
65°	7.1
65°	Occulting angle

Flight duration 15 days

Flight duration 15 balloon days

Number of orbits 0

Position last heard 83818 (07/03/67)

Balloon days tracked 15

Remarks: Strain gauge improperly installed and unable to obtain useful stress data. Balloon flew well with no indication of icing problems through 07/03/67. It was not heard on 08/03/67.

U -- strain; D -- air temperature; H -- sun angle; M -- reference.

Probable cause of failure: balloon leak or icing.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 81306 VKHD

Frequency 15.026 MHz

Method of leak test tent test

Test results no leaks found

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Schjeldahl 5

Balloon mass 2110 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 3.0 mils

Electronics mass 165 gm

Ballast 105 gm

Gross weight less helium 2380 gm

Free lift 428 gm

Launch site 172° 32'E, 43° 29'S

Launch time 23/02/67 2305 UT

Ascent rate

0 - 5,000 m 2.0 m/sec

5,000 - 9,000 m 2.5 m/sec

Float altitude 9160 m

Radar

Computed xxxx

Calibration data HHH

Sun angle	Code period (10^{-1} sec)
10°	28.0
30°	14.5
65°	6.0
65°	Occulting angle

Flight duration 3 days

Flight duration 3 balloon days

Number of orbits 0

Position last heard 72768 (26/02/67)

Balloon days tracked 3

Remarks: Balloon flew well for 3 days with no evidence of gas loss. On the first day, clouds as indicated by the sun sensor data produced an overpressure drop from 56 mb to 29 mb. On the second and third days with clear skies above, overpressure increased from 30 mb to 50 mb as the sun angle increased from 10° to 80°.

It appears that the helium temperature was 10 to 12° colder than ambient at night at 300 mb. Daytime solar heating was measured at 12 to 14°C.

H -- sun angle; V -- air temperature; D -- strain; K -- reference.

Probable cause of failure: icing.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 82307 UMSN

Frequency 15.027 MHz

Method of leak test tent test

Test results 1 leak detected and repaired

Surface winds ° m/sec

Cloud cover cirrus

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Raven 3

Balloon mass 2175 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 3.0 mils

Electronics mass 180 gm

Ballast 33 gm

Gross weight less helium 2388 gm

Free lift 425 gm

Launch site 172° 32'E, 43° 29'S

Launch time 11/03/67 1955 UT

Ascent rate

0 - 5,000 m 2.0 m/sec

5,000 - 9,000 m 2.5 m/sec

Float altitude 9100 m

Radar

Computed xxx

Calibration data SSS

Sun angle--Code period (10^{-1} sec)

10°	29.5
30°	20.0
61°	9.6
61°	Occulting angle

Flight duration 1 days

Flight duration 1 balloon days

Number of orbits 0

Position last heard 74379 (12/03/67)

Balloon days tracked 1

Remarks: Balloon went to altitude and superpressured properly. Sun sensor data from weak signals indicated heavy clouds. Data obtained for only 2 hr.

U -- air temperature; M -- reference; S -- sun angle; N -- strain gauge.

Probable cause of failure: icing.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 83305 VWHR

Frequency 15.025 MHz

Method of leak test tent test

Test results 1 pinhole leak detected and repaired

Surface winds ° m/sec

Cloud cover cirrus

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Raven 2

Balloon mass 2194 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 3.0 mils

Electronics mass 177 gm

Ballast 33 gm

Gross weight less helium 2404 gm

Free lift 432 gm

Flight duration 1 days

Flight duration 1 balloon days

Number of orbits 0

Position last heard 74379 (12/03/67)

Balloon days tracked 1

Launch site 172° 32'E, 43° 29'S

Launch time 11/03/67 2015 UT

Ascent rate

0 - 5,000 m 2.0 m/sec

5,000 - 9,000 m 2.5 m/sec

Float altitude 9080 m

Radar

Computed xxx

Calibration data HHH

Sun angle	Code period (10^{-1} sec)
10°	26.5
30°	15.8
61°	8.7
61°	Occulting angle

Remarks: V -- air temperature; W -- reference; H -- sun angle; R -- strain gauge.

Balloon flown together with 82 UMSN, 84 W, and 85 WKRD. Balloon went to altitude and over-pressured properly. Sun sensor data from weak signals indicated heavy clouds. Data obtained for only 15 hr.

Probable cause of failure: icing.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 84308 W

Frequency 15.028 MHz

Method of leak test tent test

Test results 1 pinhole leak detected and repaired

Mfr. balloon # Raven 1

Balloon mass 2182 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 3 mils

Electronics mass 162 gm

Ballast 34 gm

Gross weight less helium 2378 gm

Free lift 425 gm

Launch site 172° 32'E, 43° 29'S

Launch time 11/03/67 2220 UT

Ascent rate

0 - 5,000 m 2.0 m/sec

5,000 - 9,000 m 2.5 m/sec

Float altitude 9140 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10°	29.0
30°	19.9
80°	11.9
80°	Occulting angle

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Flight duration 1 days

Flight duration 1 balloon days

Number of orbits 0

Position last heard

Balloon days tracked 1

Remarks: Balloon was tracked for only 35 min and disappeared in clouds.

Probable cause of failure: icing on ascent.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 85307 WKRD

Frequency 15.027 MHz

Method of leak test tent test

Test results 1 pinhole leak detected and repaired.

Mfr. balloon # Raven 5

Balloon mass 2211 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 3.0 mils

Electronics mass 178 gm

Ballast 34 gm

Gross weight less helium 2423 gm

Free lift 432 gm

Launch site $172^\circ 32'$E, $43^\circ 29'$S

Launch time 11/03/67 2245 UT

Ascent rate

0 - 5,000 m 2.0 m/sec

5,000 - 9,000 m 2.5 m/sec

Float altitude 9060 m

Radar

Computed xxxx

Calibration data RRR

Sun angle	Code period (10^{-1} sec)
10°	27.1
30°	17.9
85°	8.6
85°	Occulting angle

Surface winds $^\circ$ m/sec

Cloud cover cirrus

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Flight duration 51+ days

Flight duration 53 balloon days

Number of orbits 2

Position last heard 65672 (30/04/67)

Balloon days tracked 25

Remarks: R -- sun angle; W -- air temperature; D -- strain gauge; K -- reference.

This balloon was flown together with 82 UMSN, 83 VWHR, and 84 W. All of these apparently failed within one day of launch. 85 WKRD flew for 51 days and moved into the Antarctic night on 30/04/67. It still indicated adequate overpressure and may still be flying. The only difference on this flight with respect to the others was a different antenna design permitting a suspension of the electronics 13 m below the balloon.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 86025 C

Frequency 15.025 MHz

Method of leak test factory H_2O test

Test results no leaks detected

Surface winds ° calm m/sec

Cloud cover high cirrus

Climb-out winds UT

0 - 5,000 m calm

5,000 - 10,000 m calm

10,000 m - altitude calm

Altitude calm

Mfr. balloon # Raven 104

Balloon mass 6690 gm

Balloon volume 216 m^3

Balloon diameter 7.4 m

Film thickness 1 mils

Electronics mass 169 gm

Ballast 54 gm

Gross weight less helium 6913 gm

Free lift 1244 gm

Launch site 172° 32'E, 43° 29'S

Launch time 13/03/67 1945 UT

Ascent rate

0 - 10,000 m 2.0 m/sec

10,000 - 25,000 m 2.5 m/sec

Float altitude 25,500 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	33.0
30°	20.4
64°	11.4
64°	Occulting angle

Flight duration see remarks days

Flight duration balloon days

Number of orbits

Position last heard

Balloon days tracked

Remarks: Balloon still flying on 09/06/67 on 89th day. This balloon carried 600 gm dry ice to reduce ascent rate.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 87023 J 87025 P

Frequency 15.023 15.025 MHz

Method of leak test factory H_2O test

Test results no leaks detected.

Surface winds ° calm m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Raven 103

Balloon mass 5897 gm

Balloon volume 216 m^3

Balloon diameter 7.4 m

Film thickness 1 mils

Electronics mass 325 gm

Ballast 276 gm

Gross weight less helium 6500 gm

Free lift 1200 gm

Launch site 172° 32'E, 43° 29'S

Launch time 16/03/67 1955 UT

Ascent rate

0 - 10,000 m 2.0 m/sec

10,000 - 25,000 m 2.5 m/sec

Float altitude 25,800 m

Radar

Computed xxxx

Calibration data JJJ

Sun angle--Code period (10^{-1} sec)

10°	26.0
30°	17.6
80°	10.5
80°	Occulting angle

Flight duration see remarks days

Flight duration balloon days

Number of orbits

Position last heard 76089 (28/04/67)

Balloon days tracked

Remarks: Since this balloon is equipped with a strain gauge, it is possible to monitor gas loss and estimate flight duration. Flight duration should be between 4 and 6 months. It is assumed as of 10/06/67 that this balloon remains in the Antarctic night.

J transmits sun angle information, P transmits strain data.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 88308 M

Frequency 15.028 MHz

Method of leak test tent test

Test results no leaks detected

Surface winds ° m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Raven 4

Balloon mass 2145 gm

Balloon volume 6.06 m^3

Balloon diameter 2.26 m

Film thickness 3 mils

Electronics mass 160 gm

Ballast 35 gm

Gross weight less helium 2340 gm

Free lift 425 gm

Launch site 172° 32'E, 43° 29'S

Launch time 16/03/67 2100 UT

Ascent rate

0 - 5,000 m 2.0 m/sec

5,000 - 9,000 m 2.5 m/sec

Float altitude 9500 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	29.5
30°	21.4
80°	13.7
80°	Occulting angle

Flight duration 4 days

Flight duration 4 balloon days

Number of orbits 0

Position last heard 64345 (19/03/67)

Balloon days tracked 4

Remarks: This balloon was highly stressed for 2 days prior to launch to introduce a permanent creep which provided a volume increase of 4%.

Probable cause of failure: icing.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 89305 W

Frequency 15.025 MHz

Method of leak test tent test

Test results no leaks detected

Surface winds ° m/sec

Cloud cover

Climb-out winds 1700 UT

0 - 5,000 m 330° 25 m/sec

5,000 - 10,000 m 360° 46 m/sec

10,000 m - altitude

Altitude 360° 52 m/sec

Mfr. balloon # Viron 1-B

Balloon mass 1008 gm

Balloon volume 5.04 m^3

Balloon diameter 2.13 m

Film thickness 1.5 mils

Electronics mass 158 gm

Ballast 564 gm

Gross weight less helium 1730 gm

Free lift 182 gm

Launch site 172° 32'E, 43° 29'S

Launch time 25/03/67 1945 UT

Ascent rate

0 - 5,000 m 1.5 m/sec

5,000 - 10,000 m 1.8 m/sec

Float altitude 10,500 m

Radar

Computed xxxx

Calibration data

Sun angle--Code period (10^{-1} sec)

10°	42.9
30°	23.9
80°	9.8
80°	Occulting angle

Flight duration 12 days

Flight duration 12 balloon days

Number of orbits 0

Position last heard 64913 (05/04/67)

Balloon days tracked 11

Remarks: This balloon was designed to fly at 200 mb but was heavily ballasted for flight at 250 mb.

Probable cause of failure: defect introduced by over-stressed design.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 90027 O 90026 A

Frequency 15.027 15.026 MHz

Method of leak test factory H_2O test

Test results no leaks detected

Surface winds ° calm m/sec

Cloud cover

Climb-out winds UT

0 - 5,000 m

5,000 - 10,000 m

10,000 m - altitude

Altitude

Mfr. balloon # Raven 106

Balloon mass 5886 gm

Balloon volume 216 m^3

Balloon diameter 7.4 m

Film thickness 1 mils

Electronics mass 350 gm

Ballast 264 gm

Gross weight less helium 6500 gm

Free lift 1200 gm

Launch site 172° 32'E, 43° 29'S

Launch time 25/03/67 1950 UT

Ascent rate

0 - 10,000 m 2.0 m/sec

10,000 - 20,000 m 2.5 m/sec

Float altitude 25,800 m

Radar

Computed xxxx

Calibration data 000

Sun angle	Code period (10^{-1} sec)
10°	27.9
30°	18.6
80°	10.8
80°	Occulting angle

Flight duration see remarks days

Flight duration balloon days

Number of orbits

Position last heard 66220 (23/04/67)

Balloon days tracked

Remarks: This balloon was last heard on 23/04/67. Since it was equipped with a strain gauge, it was possible to estimate life at between 2 and 3 months. As of 10/06/67 the balloon remains in the Antarctic night. Since dry ice was not available, methyl alcohol was used as a dribble ballast to reduce ascent rate. O transmits sun angle information, A transmits strain data.

GHOST BALLOON FLIGHT SUMMARY

Balloon # 91022 D

Frequency 15.022 MHz

Method of leak test factory water test

Test results no leaks detected

Surface winds ° calm m/sec

Cloud cover

Climb-out winds UT

0 - 10,000 m 270° 3 m/sec

10,000 - 20,000 m 280° 25 m/sec

10,000 m - altitude

Altitude

Mfr. balloon # Raven 102

Balloon mass 5897 gm

Balloon volume 216 m^3

Balloon diameter 7.4 m

Film thickness 1 mils

Electronics mass 160 gm

Ballast 443 gm

Gross weight less helium 6500 gm

Free lift 1200 gm

Launch site 172° 32'E, 43° 29'S

Launch time 26/03/67 1950 UT

Ascent rate

0 -10,000 m 4.0 m/sec

10,000 - 20,000 m 3.5 m/sec

Float altitude 25,800 m

Radar

Computed xxxx

Calibration data

Sun angle	Code period (10^{-1} sec)
10°	42.4
30°	21.1
64°	8.6
64°	Occulting angle

Flight duration see remarks days

Flight duration balloon days

Number of orbits

Position last heard 55610 (05/05/67)

Balloon days tracked

Remarks: Last reported position on this balloon on its 40th day at 56° S latitude with a maximum sun angle of 18°. We cannot determine as yet whether the balloon failed at this time or whether it moved into the Antarctic night.

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