Southern Hemisphere GHOST Test Program

Status Report

March-August 1966

The first six months of this cooperative New Zealand-U.S.A. test program have provided exciting results, have given great promise for a major breakthrough in atmospheric observations, and have uncovered a number of problems. Flights during these six months have been at density-altitudes equivalent to 500 millibars and 200 millibars. Flights at 30 millibars will commence in October 1966. Most of the exciting results have occured at 200 millibars and most of the problems have been found at 500 millibars.

Tracking Stations

Tracking stations have been operated for the program at Christchurch, Tahiti, Lima, Rio de Janeiro, Buenos Aires, Pretoria, Luanda, Zambia, Mauritius, and Melbourne. In addition data have been furnished by Djakarta on balloons which have moved near the Equator. Tracking ranges have consistently exceeded 8,000 kilometers for those stations with good listening locations.

Location Accuracy

With good tracking data it is possible to locate balloon position within 50 kilometers. Analysis of the sun-angle data over the entire day's transmission permits a reasonable estimate of wind velocity as well as position determination.

Duration at 200 Millibars

A complete listing of flights is attached. On 31 August 1966, the following balloons were still flying.

28203 XXX	-	125 days
34206 JJJ	-	99
39208 HHH	-	90
40204 BBB	-	87
41204 WWW	-	77
47205 AAA	-	23
48207 MMM	-	20

In addition, it is believed that Flight 27203 BBB may still be flying. It has a weak transmitter and codes eratically. It was last heard on 11 July at Djakarta on its 76th day.

The testing program for 200 millibar balloons proved to be difficult and time consuming. The technique of determining gas loss by lift measurements, which worked well with 500 millibar balloons, had to be abondoned for the larger 200 millibar balloons. An adequate test using air and Freon required at least five days before errors in measurement of overpressure, atmospheric pressure, temperature and balloon volume change permitted a reasonable prediction of flight performance. Balloons were accepted for flight when test data provided a predicted life or sixty days or better. In some cases, stable test conditions permitted the predicted life to be computed as not less than 150 days.

Below is a chart illustrating the performance of 200 millibar balloons for all flights between 30 March and 30 June which reached altitude without damage and with a working transmitter. (Flights 16202S-17206U, 21207U, 22203R, 26204K and 37202W are not included).

Predicted Life Not Less Than:	Flight Duration Not Less Than:			
	0-30 days	31-60 days	60-90 days	> 90 days
Not tested	1			
30 days	1	2		
60 days	1	2	1	
90 days	1			
120 days		1	2	1*
150 days			2*	2*

*These balloons still flying on 31 August

There is a strong correlation between predicted and actual flight duration. It would appear that balloons, for which predicted life was 90 days or less, had small holes which were not detected in the ground tests. These holes increased in size during flight--perhaps through ablation by the high-speed jet of escaping helium. Balloons which indicated a life of 120 days or better in the tests have performed quite well. The average life of these balloons should exceed 120 days.

The testing effort in the field to ensure 120 day life is too onerous. Emphasis is being placed on improved quality control, inspection and test at the factory. A new group of balloons with more intensive control at the factory is now under procurement. Flight of these new 200 millibar balloons will begin in October.

It is still too early to determine how closely we can approach the theoretical life of the balloons at 200 millibars. For the balloons to be flown in October and following months, the theoretical life is more than two years.

Duration at 500 Millibars

Ten flights were made during March at 500 millibars. Since only the Melbourne and Christchurch tracking stations were operational during March, the duration figures listed in the attached summary are shaded on the very low side. The longest verified flight was 19 days. A typical flight history consisted of several days of excellent data followed by a day on which the sun angle sensor indicated thin clouds above the balloon. The balloon would not be heard for the next several days. In one case (06508 KKK) the balloon survived its flight through super-cooled clouds and reappeared. Balloons flying in tropical latitudes survived for longer periods than balloons moving through frontal systems in temperate latitudes. Two balloons launched immediately after a frontal passage failed to survive as they were carried by high winds at 500 millibars through the frontal zone.

Experiments with increased lift and surface-treatment to increase water shedding have been only partially successful. The combination of greater lift and improved shedding ensures that the balloon can fly through warm clouds. However, we do not as yet have a combination of increased lift and ability to shed ice which will ensure long duration flight. The plans for solution of the problem are included in a later section.

One puzzling and promising development was the reappearance of Flight 32506 DWRK on 17 July after contact was lost on 17 May. This balloon was surface-treated and flown with 22% free lift on 12 May. The balloon was monitored for five days from Christchurch and then lost. How it managed to survive for 60 days and escape the tracking network remains a puzzle. It appears that it moved across the Equator. / No position fix was possible from the limited data obtained at Djakarta. The identification appears conclusive since the balloon was transmitting as a four-coder and no other conceivable source could have provided the unique four-code pattern at the assigned frequency.

<u>Stability</u>

One of the questions to be answered during the GHOST tests is how stably do the balloons fly.

No direct measurements have been made at 200 millibars except that many of the balloons were equipped with radar targets and tracked into altitude with the Christchurch radar. The balloons leveled out at design altitude (density of 0.321 kg/m^3) within 100 meters whenever the radar elevation was high enough to permit altitude measurement. It is assumed that balloons will fly more stably at 200 millibars than at 500 millibars. Test emphasis was placed on making accurate measurements of stability at 500 millibars.

The following table illustrates the stability of a balloon flying at a predicted flight level of 0.697 kg/m^3 (the weight of instruments forced us to fly below the density level of 0.692 kg/m^3 - the density corresponding to 500 millibars in the standard atmosphere).

"500 Millibar" Balloon Flight - Stability Test

Day	Balloon Time	Pressure	Air Temp.	Helium Temp.	Super Temp.	Density	$\Delta\rho$*
1	Noon	527mb	$-12^{\circ}C$	$-8^{\circ}C$	$+4^{\circ}C.$	.701kg/m^3	-44 meters
	Late	530	- 9	- 9	0	.697	0
	Night	532	-11	-16	- 5	.705	-87
2	Noon	524	-11	- 9	+ 2	.695	+22
	Late	526	-10	-12	- 2	.695	+22
3	Early	522	-12	-11	+ 1	.694	+33
	Noon	521	-12	-11	+ 1	.693	+44
	Late	521	-13	-11	+ 2	.696	+11
4	Noon	528	- 9	- 9	0	.695	+22
5	Noon	533	- 6	- 5	+ 1	.695	+22
	Late	540	- 3	- 5	- 2	.696	+11
6	Noon	534	- 5	- 6	- 1	.693	+44
7	Noon	533	- 6	- 7	- 1	.695	+22

*$\Delta\rho$ - Deviation in "density-altitude" from the 0.697kg/m^3 surface

Note that after the first day the measured maximum deviation from the average density-altitude of 0.695 was 22 meters--corresponding to a pressure error of 1.5 millibars or a temperature error of $1^{\circ}C$. The actual deviation must have been less than 10 meters during daylight hours. The sunset effect was measured as $8^{\circ}C$. On the fifth, sixth and seventh days, the balloon was over the tropical Pacific (20° to 30° latitude). Note the balloon skin temperature was colder than air temperature during daylight hours in the tropics.

Balloon Supertemperature

In the previous table the variation in supertemperature (commonly called superheat) of the lifting gas is indicated for a seven day period during the summer months over the tropical and temperate ocean areas at 500 millibars. The amount of skin heating is surprisingly low for a thick-walled (2.5 mil) balloon. A test flight over the U.S.A. provided data at 200 millibars. Additional flights will be made to provide data at all altitudes from 500 millibars to 30 millibars.

Tentative conclusions based on these flights and previous flights by the Air Force Cambridge Research Laboratories and the Naval Research Laboratory are tabulated below. These will be refined as additional flights are made.

Altitude	Region	Air Temperature	Nightime Helium Supertemperature	Solar* Heating
500 mb	Tropical	- 5°C	-8° ± 4°C	+ 8°C
500	Temperate	-15°	-2° ± 6°	+ 8°
500	Arctic	-25°	?	+ 8°
200	Tropical	-45°	0° ± 4°	+ 9°
200	Temperate	-55°	6° ± 6°	+ 9°
200	Arctic	-55°	?	+ 9°
30	Tropical	-55°	0° ± 4°	+10°
30	Temperate	-55°	0° ± 6°	+10°
30	Arctic	-60°	?	+10°

*The solar heating is increased over land areas on clear days by the increased outgoing radiation from the warmer ground. The solar heating is also increased by reflected radiation from cloud decks below the balloon

Electronics Temperature

The GHOST electronics package consists of a black plastic hemisphere capped with a white-painted epoxy board. The solar cells are mounted on the epoxy board. At 200 millibars the internal temperature varied from 0°C at low sun-angles to +30° at high sun angles. A 10 cm^2 area was removed from the base of the hemisphere to provide additional cooling. During 40 days of flight at 200 millibars a package with this configuration did not vary in daytime temperature above +20°C or below -5°C. The coldest temperatures occured at the highest sun angles.

At 500 millibars the unventillated package temperature rose to +40°C at sun angles above 30°. The addition of a 55 cm^2 vent area at the base of the hemisphere and four 1.2 cm^2 holes at the top of the hemisphere reduced temperatures to acceptable values. Temperatures during daytime remained between +5°C and +15°C.

Meteorological Data

Tracking data from Tahiti, Melbourne and Christchurch are analyzed each day and position reports distributed from Wellington throughout WMO Region 5.

Data from all tracking stations are mailed to Boulder, Colorado for analysis. Initial tests indicate that data quality is good enough to compute both position and velocity for the balloon trajectory. Analyzed data will be distributed for all balloon trajectories from Boulder in the near future. Production of these data may be delayed for at least two months because of the movement of the CDC 6600 computer to the new NCAR facility.

Plans - 30 Millibars

Launch of 30 millibar balloons will begin at Christchurch in October 1966.

Plans - 200 Millibars

Flights have been delayed in July and August at Christchurch by seasonably poor weather and by the poor ground test performance of the remaining balloons on hand. A new production of balloons of improved design is underway. Launch of these balloons should begin in October or November 1966.

Plans - 500 Millibars

The following projects are underway to improve performance of 500 millibar balloons:

a) Flight test of cylinder balloons at lower altitudes to determine weather susceptibility as a function of altitude.

b) Limited flight tests of higher lift (25%) surface-treated balloons.

c) Development of very high lift (50-70%) balloons for 500 millibar flight.

d) Laboratory research on surface treatments to improve ice and water shedding.

e) Design of much larger balloon systems to increase the volume to skin area ratio.

If reliable flight at 500 millibars does not prove feasible with existing materials and techniques, an alternate approach remains open. The EOLE flights have demonstrated that balloons can be flown successfully at 300 millibars. Flight tests will be made to determine if long duration can be achieved at 400 millibars. If tests are successful at 400 millibars, a balloon system will be used in which an instrument package will be deployed several hundred meters below a balloon flying at 500 millibars. Wind Shear measurements will be used to extrapolate the 400 millibar wind field to 500 millibars. A technique has been developed which permits easy deployment of long balloon trains with surface winds up to 10 knots. The line (2 to 3 kilograms breaking strength) does not constitute a hazard in the air or on the ground. A successful test flight with the payload deployed 1600 meters below the balloon has been made at Boulder. No technical problems exist in the development of the instrument system to measure wind shear. It appears that a 600 meter line will be sufficient to permit adequate extrapolation of the wind field from 400 millibars to 500 millibars. The entire system will follow the wind field at 400 millibars with an error not exceeding 1 meter per second under the most severe conditions. This error is eliminated entirely by floating the balloon approximately 100 meters above the 400 millibar level.

Plans - Program Extension

Since we are now confident that the trajectory data is adequate for estimation of wind velocity as well as balloon position, the possibility exists of providing synoptic data with the present location techniques. The number of balloons which can be tracked at one time is limited to less than 100. We must await the development of the balloon-satellite system before it will be possible to track large numbers of balloons. However, a pilot program, in which fifty balloons are tracked at all times and data quickly relayed to the meteorological services, should provide a useful interim capability in the data sparse areas.

Only three to four "real-time" tracking stations would be needed to provide adequate Southern Hemisphere coverage. With the approval and cooperation of the Southern Hemisphere nations, this pilot program could follow on within a few months of the completion in March 1967 of the existing GHOST balloon test program.

Southern Hemisphere GHOST Test Flights - March - August 1966

nPPf	M	hhddm	N	F	Last Heard	D	G	Remarks
01505 02503	V U	17-04 March	V6	10	08 March	4	100	V-sun angle sensor U-electronics temperature
03505 04506	W B	18-05 March	V5	10	10 March	5	120	W-sun angle sensor B-sun angle sensor
05507	R	18-07 March	V3	10	20 March	13	100	
16508	K	18-07 March	V2	10	26 March	19	100	
07502	G	00-10 March	S3	10	10 March	1	80	Launched after frontal passage
08504	F	00-10 March	V8	10	10 March	1	100	Leak repaired Launched after frontal passage
09505 10505	H N	18-12 March	S19	10	25 March	13	100	H-sun angle sensor N-sun angle sensor
11503 12504	M A	18-15 March	S18	10	22 March	7	100	M-sun angle sensor A-sun angle sensor
13518	L	18-17 March	S	12	23 March	6	180	12 gore balloon-flight at 500 millibars
14507	VKUM	18-22 March	S20	11	23 March	1	110	four coder-reference, sunangle, helium temperature and gas temperature
15253	D	18-24 March	R128 S	6	28 March	4	not tested	"Anchor" balloon flight at 250 millibars
16202 17206	S U	00-30 March	S6	9	30 March	0	60	S-electronics temperature U-sun angle sensor Balloon rose to 5,000 meters, iced up and descended into ocean

nn-flight number
PP-pressure-altitude in tens of millibars
f -frequency in kilo Hz (15,02f Hz)
M -Morse Code letter(s)
hh-hour of launch (GMT)
dd-day of launch
N -balloon manufacturers number
F -percent free lift
D -duration not less than [] days
G -expected flight time on ground tests [] days

	L	22-30	March	S8	10	12 June	74	60	Flight at 182 millibars
19203	G	19-05	April	S7	10	14 May	39	60	Leak repaired G-electronics temperature
20206	V								V-sun angle sensor
21207	U	22-06	April	S9	10	24 April	18	90	Rough launch - possible balloon damage
22203	R	22-06	April	S10	10	14 April	8	90	Rough launch - possible balloon damage
23206	F	19 10	April	R127	10	30 May	50	30	Leak repaired
24202	S	19-12	April	S12	10	9 July	88	120	
25209	A	19-14	April	S11	10	14 May	30	30	Leak repaired
26204	K	19-18	April	S1	10		0	120	Balloon iced up in altostratus. Did not reach ceiling
27203	B	22-26	April	S2	10	11 July	76+	120	Leak repaired Defective transmitter. Heard on 11 July in Djakarta
28203	X	19-28	April	S3	10	31 August	125+	150	
29204	Z	19-03	May	S4	12	3 June	31	120	
30202	C	20-08	May	R129	11	16 June	39	30	Leak repaired
31206	D	20-08	May	R131	11	26 May	18	60	
32506	DWRK	21-12	May	SR2	22	17 May	5*	150	Wax-treated - Four coder sunangle, air temperature, film strain and electronics temperature *Heard on 17 July in Djakarta
33504	P	20-16	May	SR1	30	19 May	3	150	Wax-treated. Glass-tape reinforcing girdle
34206	J	04-25	May	S18	14	31 August	99+	120	
35203	R	04-25	May	S19	14	18 June	25	90	
36204	K	04-25	May	S20	14	2 July	39	60	

nnPPf	M	hhddm	N	F	Last Heard	D	G	Remarks
2	W	19-26 May	S17	14	11 June	?	not tested	Defective transmitter
38206	U	19-26 May	S16	14	31 May	5	not tested	
39208	H	20-02 June	S13	14	31 August	90+	150	Seven day leakage test
40204	B	00-06 June	S15	14	31 August	87+	150	Seven day leakage test
41204	W	22-15 June	S14	14	31 August	77+	150	Five day leakage test
42502	P	21-28 June	S17	25		0	150	Wax-treated. Launched through heavy overcast. Did not reach ceiling.
43502	N	19-29 June	S16	25	1 July	2	150	Wax-treated
44205	N	20-14 July	R122	14	17 July	3	---	
45202	C	20-25 July	R116	14	29 July	4	---	
46505	P	20-31 July	S14	25	8 August	9	150	
47205	A	20-08 Aug.	R121	14	31 August	23+	---	Leaks repaired
48207	M	20-11 Aug.	R115	14	31 August	20+	---	Leaks repaired
nnPPf	M	hhddm	N	F	Last Heard	D	G	Remarks

nn - flight number
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