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FINAL REPORT
1967 Suntracker Balloon Flights
Flights 3042, 3043, 3044 and 3045

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TECHNICAL CONTENT STATEMENT

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

ABSTRACT

High-altitude solar-cell calibration was conducted during July and August 1967, using balloon techniques. Solar-cell modules, supplied by Jet Propulsion Laboratories, were flown on three 80,000-ft flights and one 120,000-ft flight. Accurate solar-cell output data was telemetered and recorded during each flight and the data delivered to JPL. This report contains the operational details of the flights, discussion of instrumentation improvements made during the program and a tabulation of secondary temperature and calibration data recorded during the program.

FINAL REPORT

Suntracker Balloon Flights

Flights 3042, 3043, 3044 and 3045

1.0 INTRODUCTION

1.1 General

Flights 3042, 3043, 3044 and 3045 were a planned series of four balloon flights conducted during July and August 1967, for Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, under subcontract 951910 to JPL. This contract provided for all necessary balloon flight services, including those required for flight preparation, functional verification of the flights and data acquisition systems, tracking of the balloon aloft by aircraft, and the recovery and return of equipment after its descent to the surface. Meteorological services were included in this contract. Balloons, helium, power supplies, antennas and other equipment required for the flights were supplied separately under purchase order EU-389512.

This report discusses each flight in detail, describes system changes made preceding and during the flight operations and provides analysis of the system discrepancies occurring during the program. Although the primary solar cell output data was delivered to JPL at the conclusion of the final flight, the appendix of this report contains secondary temperature data, calibration data, balloon characteristics and flight time-altitude profiles.

1.2 Flight Objectives

(1) Launch and ascend to an altitude of 80,000 ft. ± 4000 ft., three balloon systems with suntracker, solar cells, and instrumentation mounted atop the balloon; with telemetry and other instrumentation, and power supply mounted below the balloon. Launch a similar system to achieve an altitude of 120,000 ± 6000 ft.

(2) Telemeter altitude and solar cell data during ascent and during a floating period of four hours, minimum. The floating period shall commence before 11:00 Central Daylight Time (CDT) and shall be maintained until 15:00.

(3) Descent to surface with balloon and payload intact.

(4) Deflate balloon automatically upon impact by firing an explosive cord which opens the side of the helium filled balloon bubble for the purpose of recovering the top-mounted suntracker and solar cells with minimum damage.

(5) Recover and return all equipment, except the balloon, to Litton.

2.0 TECHNICAL DISCUSSION

2.1 Flight 3042

2.1.1 Flight Preparations

2.1.1.1 Project Personnel Assignments

Litton personnel responsible for preparations and flight operations on Flight 3042 were:

Project Engineer:	R. Conlon
Flight Leader:	M. Lueders
Instrumentation:	E. Minnich L. Nelson
Additional Launch, Tracking and Recovery Crew:	V. Schwalbe R. Olson R. Dungan D. Harshman

The same personnel conducted all flights on this program.

2.1.1.2 Pre-Flight Checkout

Required repairs and preventive maintenance were performed on all ground-station electronic support equipment. An air-conditioned telemetry van was outfitted to house the ground-station equipment.

Four significant revisions were made in the instrumentation payload preceding the flight program:

- a redesigned drive circuit for the primary data commutator
- a new power supply configuration
- repackaging the lower payload instrumentation panel
- installation of slip clutches in each suntracker.

The data commutator switch drive was redesigned to improve commutator reliability and to reduce system current drain. The original design used a governed dc motor driving a cam-microswitch arranged to pulse a remote rotary solenoid stepping switch. A 3 amp pulse of 2 seconds duration was applied to the stepper at 15 second intervals. The pulse was sent to the stepper through the long balloon power cable. This year's new design, shown schematically in Figure 1, uses a similar high current stepping switch but eliminates the remote motor and mechanical switching components. The motor previously used failed several years ago in flight and the replacement motor displayed intermittent operation after last year's program. The new driver is completely solid-state and is located in Electronic Box #1 with the stepper on the suntracker mounting plate.

Referring to the schematic, Figure 1, a 2N1671A Unijunction transistor, with a large RC time constant at its emitter, provides a 15-second time base for the desired switching rate. As the voltage on the 47 μf timing capacitor reaches the peak-point voltage of the unijunction, the transistor conducts to discharge the capacitor and produce a negative output pulse at its base #2 terminal. The negative pulse is coupled to a high current driver circuit that features a constant turn-on time independent of input pulse amplitude or duration. The two transistor driver acts as a monostable circuit in that the first transistor is normally on and the second normally off. A negative input pulse is coupled through a diode to turn the first transistor off which biases the output transistor on. This transistor is held on by feedback; the on-time is determined primarily by the 68K Ω resistor and 1 μf capacitor time constant. An on-time of 40 milliseconds was found best for this configuration.

The circuitry described above reduces average current drain from 400 to less than 80 ma. However, an important consideration is the required peak current, since it determines battery size. The stepper requires a 3 amp pulse for reliable switching and sending this current through the long balloon cable results in a significant voltage drop. The battery pulse current capacity and voltage drop factors were reduced to insignificance by the addition of a 470 Ω resistor – 2000 μf capacitor charging circuit added to the output stage of the circuit shown in Figure 1. In this arrangement the large value capacitor supplies the required peak current when the driver output transistor is turned on. The resistor recharges the capacitor during a comparatively long off-time. Maximum peak current is less than 100 ma and average current drain is less than 50 ma with this circuit modification.

For convenience during system and preflight checkouts, a manual speed-up switch was added to the Box #1 case. Depressing a normally open push-button causes a 2-second time base to be generated thereby speeding the complete 24-position data sequence to 48 seconds instead of 6 minutes. This feature was easily included by the addition of only the switch and a single timing resistor selected so that when paralleled with the 15-second timing resistor, the total resistance is reduced to produce

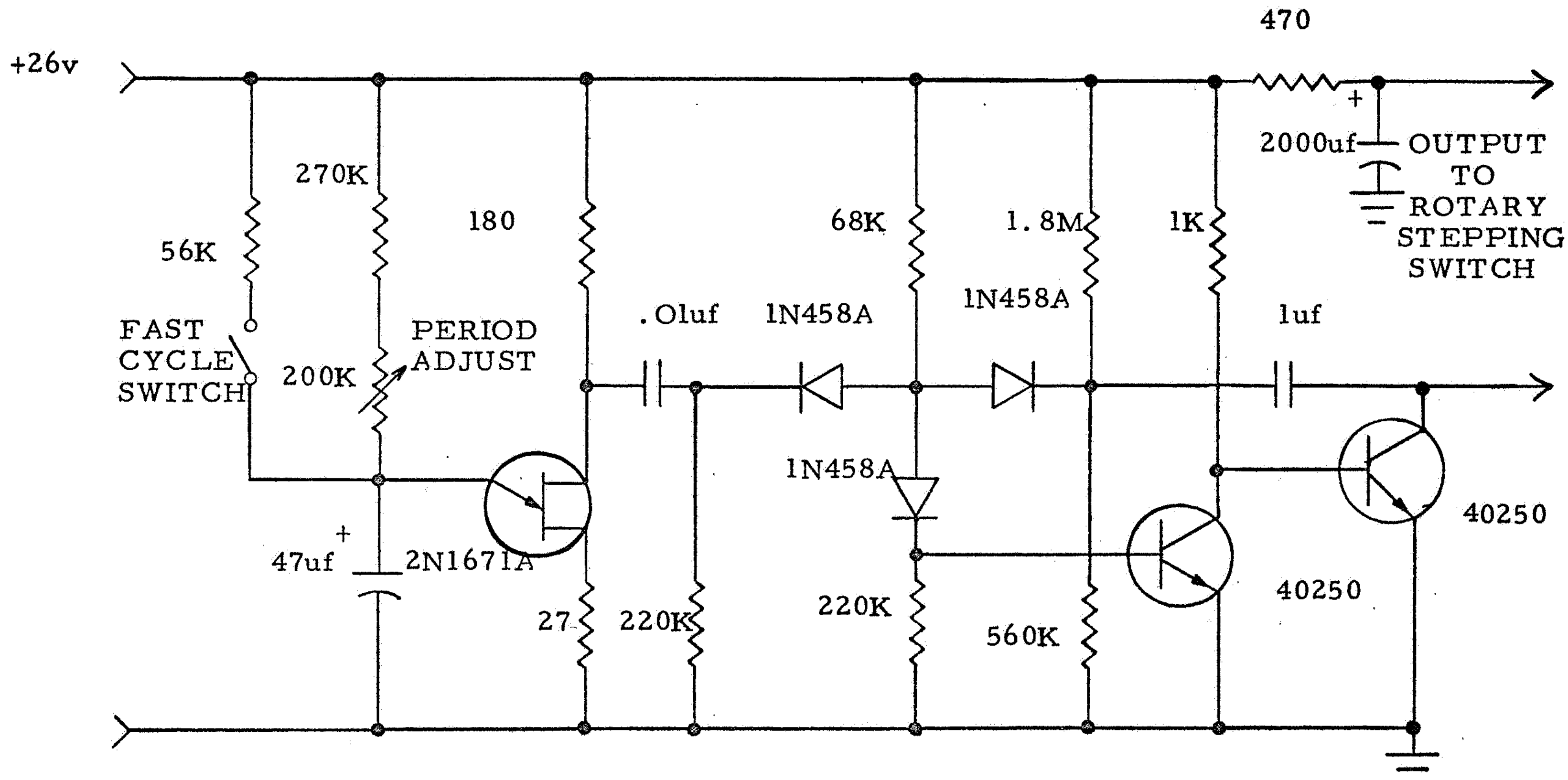


Figure 1. Data Commutator Switch Driver Schematic

9

a two-second time base. The circuitry was packaged and tested at combinations of voltage and temperature in excess of those encountered in actual use. The circuit performed perfectly with applied voltages of 16 to 26 volts at internal temperatures of -20 to +160°F.

The airborne battery power supply was completely redesigned for this year's flights. The redesign was done to reduce system weight and isolate several system functions. Weight reduction was desired to obtain an increase in float altitude to reduce the chance of operating below the prescribed minimum altitude. Power supply isolation was desired to reduce the possibility of electrical interference between the telemetry system and the beacon transmitter or the suntracker. Power packs using nickel-cadmium, lead-dioxide, alkaline-magnesium or lead-acid batteries were investigated. The final battery configuration is shown in Figure 2. The main power source is a comparatively lightweight, aircraft type, lead-acid battery. Two 12-volt sections and a single 2-volt cell are wired in series to provide power for the telemetry transmitter, stepping switch, heaters, regulators and voltage converter. A capacity of 35 ampere-hours at 26 volts is provided. The beacon transmitter-altitude coder is isolated and powered by a 24-volt pack of alkaline-manganese dioxide zinc dry batteries. This pack has a nominal capacity of 10 ampere-hours at the operating current. The suntracker is also isolated and operated by a 30-volt alkaline dry battery pack. This pack is similar to the 24-volt battery except the cells are rechargeable and rated at 4 ampere-hour capacity with a 1-ampere current drain after 30 charge-discharge cycles. This pack has a nominal capacity of 10 ampere-hours for the initial discharge at the suntracker operating current.

The alkaline cells discussed here are similar in size and appearance to ordinary carbon-zinc dry cells. However, they offer much higher service capacity and lower internal impedance. The chief advantage of the alkaline-manganese system lies in its ability to work with high efficiency under continuous or heavy duty, high drain conditions where the ordinary dry cell is unsatisfactory. Alkaline cells contain 50 to 100 percent more total energy and under high current use will provide as much as ten times the service of carbon-zinc cells. Superior low temperature performance to -40° F is another big advantage when used on balloon flights. Total power supply weight is 78 lbs compared with 108 lbs last year.

Redesign of the data commutator driver and power supply necessitated making many wiring changes to the lower instrument panel of the flight gondola. Instead of adding patch-work to this panel, a new panel was constructed. The new panel features improved thermal characteristics; logical circuit, fuse and switch arrangement; and greatly improved appearance.

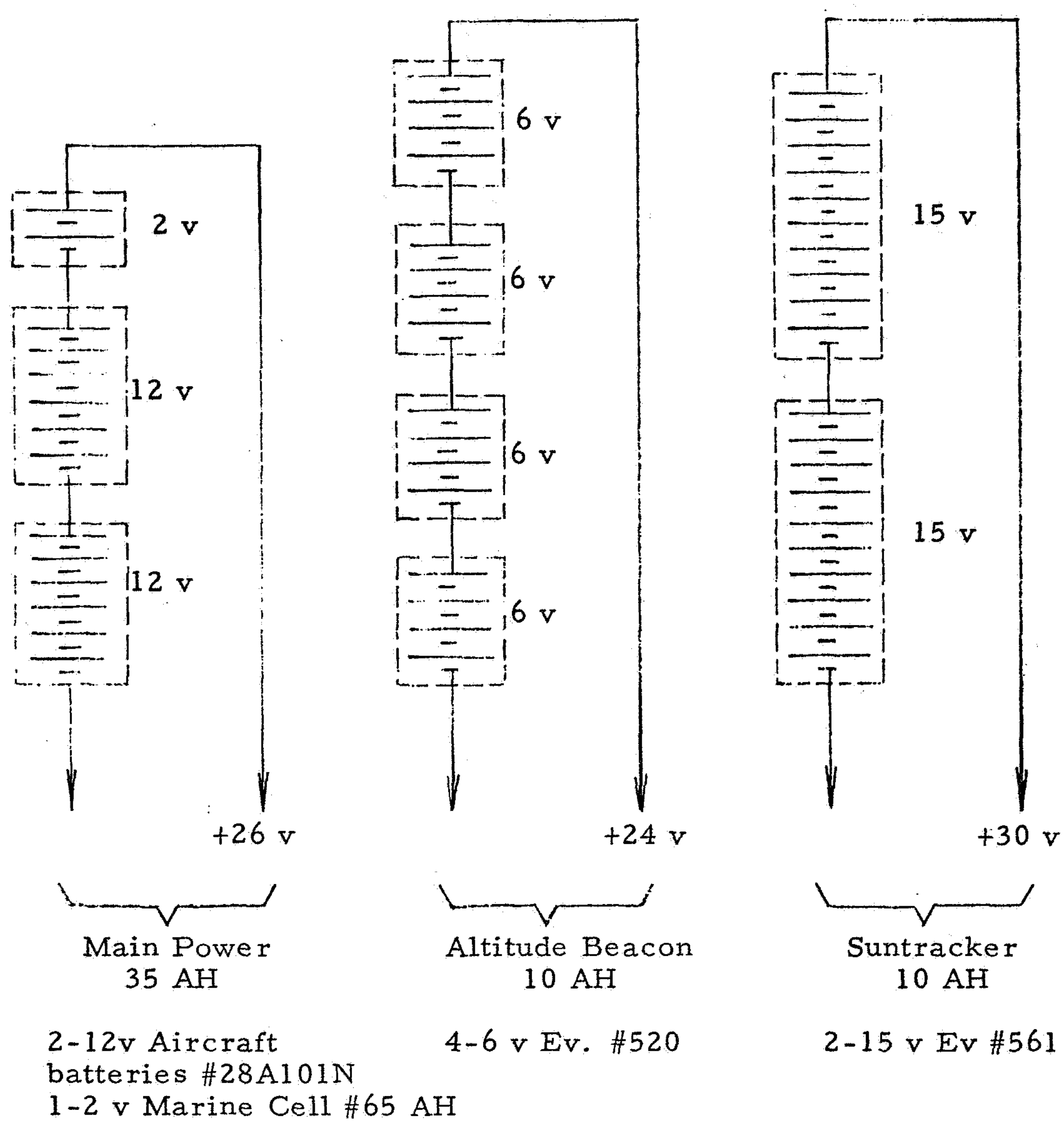


Fig. 2. Schematic of Revised Flight Power Supply

The two suntrackers were modified to accommodate slip-clutch assemblies in their elevation drive trains. The modification was done without major re-work and the initial checkout demonstrated satisfactory operation. This modification reduced tracker set-up and checkout time significantly. Installation of slip clutches allowed bypassing the troublesome motor cutoff limit switches, eliminating a potential source of trouble.

The 100 milli-volt on-board voltage reference circuitry was calibrated with a Leeds and Northrup Model K3 voltage potentiometer and Eppley Standard Cell. Voltages and corresponding subcarrier frequencies were similar in value to those recorded on the previous year's program and the voltage divider did not require adjustment. A chart containing actual voltages and frequencies obtained in final calibration is given in the Appendix, page A-5. Primary temperature channels were calibrated using a resistance decade to simulate temperature levels of 0, 20 and 40°C. The primary temperature reference channel designated B1 was used as an additional solar cell thermistor channel on this flight. This permitted recording several additional resistance versus subcarrier frequency data points so that an accurate calibration curve could be obtained. Secondary temperature circuitry was checked; the commutator was cleaned, and the output frequencies monitored and found nominal. Modulation voltage levels from the data subcarrier, temperature subcarriers, and on-sun sensor were checked and found nominal. Again this year a motor-driven timer and a pressure switch were installed in the power lead of the baro-transmitter so that altitude data transmission would be on continuously below 75,000 ft and be turned off above this altitude, except for a 2-1/2 minute on period every 10 minutes. The 7-1/2 minutes off time would allow noise-free data recording 75 percent of the time; the on time is required to monitor float altitude and obtain a radio direction fix on the system, if necessary.

As a final system check, the entire top-mounted payload was attached to the tracker-mounting disc and the balloon top end fitting. Actual balloon and parachute cables were connected and the system put in operation while in the sun. System performance was excellent with no sign of noise or instability.

2.1.2 Field Operation

2.1.2.1 Launch

The initial flight of this program was cancelled on the 12th and 13th of July due to high surface winds. Pre-launch activity began at 05:30 CDT on 14 July 1967. At 06:00 the auxiliary power supply was attached and system warm-up began. Balloon layout and system checkout were completed and inflation began at 08:00. Inflation and final checkout were completed without incident and launch was accomplished at 08:35. Bubble downwind dynamic launch technique was used with the lower payload mounted on the front of the launch vehicle. The same launch technique was used on all flights of this program.

2.1.2.2 Tracking and Recovery

A four-man crew consisting of a Cessna 170 pilot and observer/radioman, and on the ground, a truck driver and an assistant driver/radioman, handled the tracking and recovery. Operations were directed by the telemetry-control base station. Flight No. 3042 took a southerly course during ascent to a point 5 miles southwest of Faribault, Minnesota at 10:19 CDT, the beginning of the float period. During float the system moved due west to a point 10 miles south of Marshall, Minnesota at 15:00, where the onboard flight timer initiated descent by opening a helium gas port. The system continued west during initial descent to a point 10 miles from the South Dakota border at 55,500 ft altitude at 16:00 hours. The remainder of descent was in a south-southeasterly direction to an impact point 3 miles southwest of Adrian, Minnesota, at 17:18. Touchdown was in an open pasture and the recovery crew was at the site. They were able to observe impact and detonation of the balloon destruct device. The explosive cord destruct device opened the balloon but a light surface wind twisted the bubble to trap the remaining lift gas before it had escaped. The system was dragged across the pasture a short distance by the surface wind until the recovery crew drove up and secured the lower payload to the recovery vehicle. The crew then manually split open the balloon to release the remaining gas and packed up the undamaged flight equipment. The crew returned to Minneapolis late that evening with all gear in excellent condition.

2.1.3 Flight Results

2.1.3.1 Balloon

The balloon used on this flight was similar in diameter and carried the same model number as those used on this program in previous years. Design details are included in the operational specification sheet included in the Appendix, page A-1. A load-altitude curve of the balloon is also in the Appendix, page A-2. The flight system configuration was identical to last year's (see Figure 3).

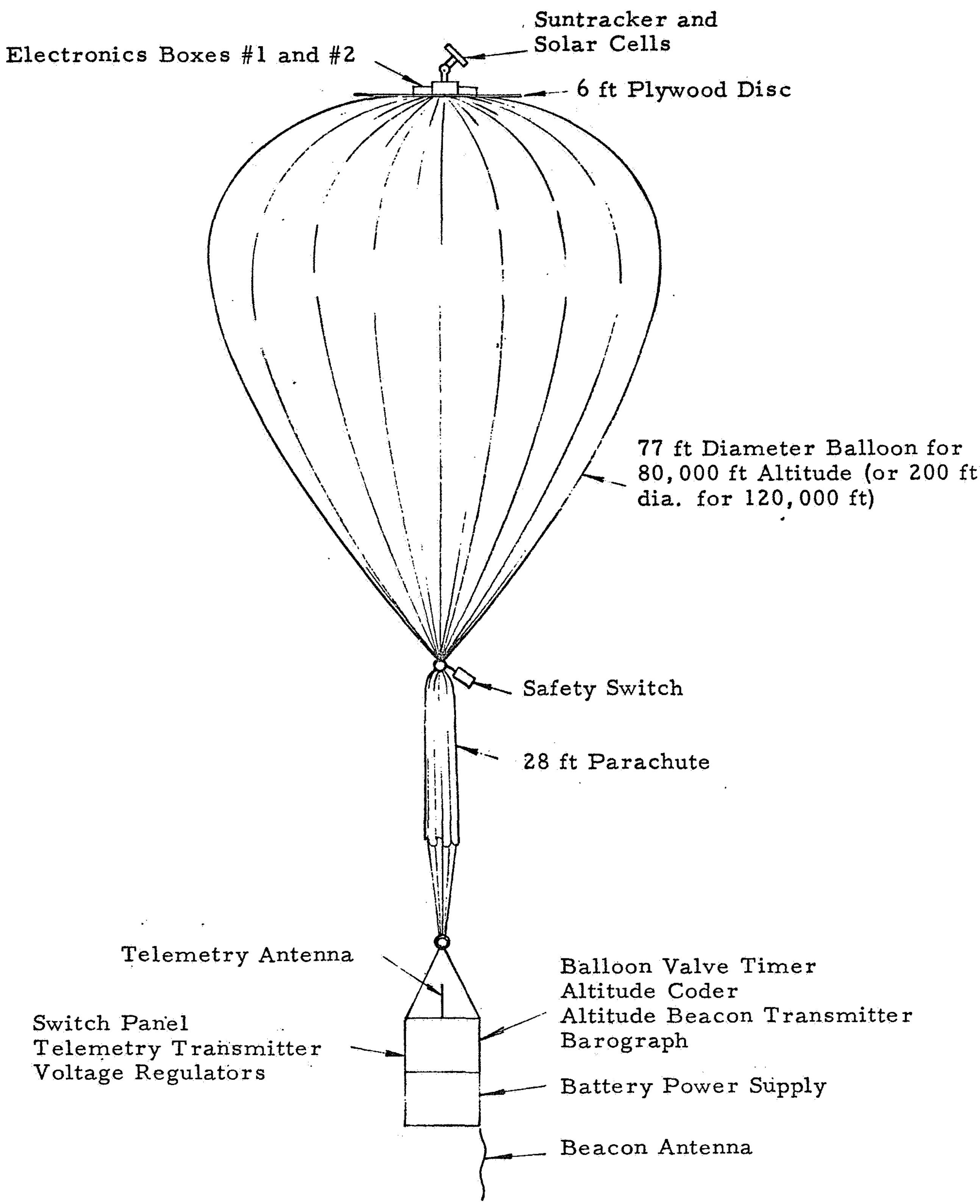


Fig. 3. Balloon Flight Configuration

19

Using 8 percent free lift, the average rate of rise was 762 fpm (feet per minute) to a float altitude of 80,000 ft. Average float altitude was approximately 79,100 ft and it varied less than plus or minus 1,000 ft throughout the float period. The low altitude limit was penetrated at 10:09 and the system remained above 76,000 ft for a period of 5 hours, 4 minutes.

2.1.3.2 Instrumentation

All components of the tracking-telemetering system performed flawlessly throughout the flight. There were no minor discrepancies; the received data was very stable and clean. There was no interference -- even when the baro-transmitter was operating -- during the floating period. All telemetered reference voltages were within plus or minus one Hertz of their nominal frequency during the entire float duration.

The solar tracker was actuated at 19,500 ft. The telemetered on-sun signal indicated normal tracker operation with nearly continuous tracker angle corrections due to balloon rotation on ascent. After float equilibrium was attained, the on-sun sensor indicated only infrequent corrections. The solar cell data recorded with the analog record represented a positive indication that the tracker was, in fact, pointed directly at the sun at all times, except during brief and infrequent rewind periods. Since the tracker was not subjected to any severe shock or mechanical abuse during any part of the flight, the newly installed slip clutch could not be judged on its ability to prevent tracker drive mechanism damage. The clutch proved very useful, however, during final checkout and set-up. This modification allowed test personnel to pre-set the elevation angle to any position, providing an excellent final flightline check of the tracker's ability to home-in from extreme off-sun angles. The tracker could also be easily pre-set to the approximate turn-on elevation angle before inflation, further minimizing the chance of a false lock-on during balloon ascent.

The new data stepping switch drive circuit operated without fault throughout the flight. The analog record indicated that there were no skipped or missing data channels. The delay time between steps was monitored with an electronic counter at intervals during the flight and found to be within one-half second of the nominal switching time.

Secondary temperature telemetry (Appendix A-6) and lower payload instrumentation temperatures (Appendix A-10) provided an interesting comparison of system thermal characteristics with data from previous flights. As expected, from the redesign accomplished preceding the flight, both the Box #1 and gondola instrumentation temperatures averaged lower than before. Although

VCO, Disc, Tracker and Box #2 thermistor temperatures were similar to previous data, Box #1 temperature ranged from +17 to +34°C compared to average temperatures of +32 to +48°C in the past. The lower temperature range is a direct result of reduced power dissipation of the data stepping switch. The graph of recorded lower payload temperature reveals that the maximum was only +34°F compared to typical maximums of +80° to +100°F last year. This large temperature decrease was the result of repackaging the instrument panel components, adding a new heat dissipator to the panel and painting the entire lower payload flat white. This data indicates that due to the improved configuration the white cardboard sun shield normally attached just above the gondola may no longer be required on future 80,000 ft flights. To test this theory, the shield will not be flown on the next flight.

16

2.2 Flight 3043

2.2.1 Flight Preparations

The same system components flown on Flight 3042 were set up for this flight. After the solar cell modules were replaced with the units prepared for the second 80,000 ft payload, the solar tracker was given a preliminary on-sun test. A slight increase in the elevation drive sensitivity was the only adjustment made to the unit. The on-sun circuit modulation levels and secondary temperature circuit were tested and found not to have changed from the previous flight. Final calibration of the reference voltages showed them to be essentially the same as when checked before Flight 3042; see Appendix page A-5.

The three separate battery sets flown on the first flight were tested to determine the reserve capacity. Each battery had considerable remaining capacity, indicating that the new battery configuration is satisfactory. The main power wet cells were recharged and the dry cells replaced and tested under load during the pre-flight checkout. The beacon-altitude instrument was recalibrated and the timer and pressure switch device used to cut off the altitude signal at float altitude was checked for reuse. This timer was included as an additional safety backup to reduce the possibility of radio frequency interference with the telemetry data, this despite the fact that there was no interference during the previous flight. All pressure actuated switches were checked and, after an on-sun test of the entire system, it was judged ready to fly.

2.2.2 Field Operation

2.2.2.1 Launch

Launch preparations for Flight 3043 began on schedule on 25 July 1967. Balloon layout began at 06:53 CDT with wind velocity 2 miles per hour. System checkout proceeded smoothly; inflation began at 08:04 and was completed at 08:30. The system was released at 08:37. The dynamic launch was not smooth under low velocity-variable direction wind conditions. Launch vehicle speed and payload release timing became more critical under these conditions. The timing was not optimum in this situation and as a result the lower instrument package slid off the side of the launch frame after release. Fortunately, the box cleared the vehicle without damage and without any panel switches being actuated.

2.2.2.2 Tracking and Recovery

The system ascended on a southeasterly course and reached float equilibrium over Durand, Wisconsin at 10:55 CDT. The wind at float altitude moved the balloon to the northeast over St. Paul and to a point 3 miles north of Rockford, Minnesota at 15:00, the conclusion of the float period. Descent course was again southeast, toward St. Paul. The system crossed the heavily populated metropolitan area at low altitudes but impacted in an open rural area 6 miles east of the downtown St. Paul airport. The area was covered with high grass and small trees and there was no damage to crops or fences. The destruct device was actuated but the lower payload was dragged several hundred feet until manually restrained and deflated by the recovery crew who were at the site within five minutes of impact. The undamaged equipment was loaded and brought back to the plant without incident.

2.2.3 <u>Flight Results</u>

2.2.3.1 Balloon

The balloon design and material were identical to that used on the previous flight. Using 8 percent free lift, the average rate of rise was 580 fpm to 80,000 ft. The rate of rise was less than normal; the reason for slow ascent rate is not known. Maximum altitude was 80,000 ft and minimum altitude was 78,500 ft during the float period. The flight ascended through the 76,000 ft level at 10:45 and remained above that level for four hours and thirty minutes.

2.2.3.2 Instrumentation

As on the previous flight, all components of the entire system performed flawlessly throughout the flight. The telemetered reference frequencies did not vary more than plus or minus one Hertz during the data sampling period. The solar tracker turned on as programmed and operated properly for 7-1/2 hours The tracker and its solar cell payload was not damaged on impact. Secondary temperature telmetry was good and temperatures recorded (see Appendix A-7) were practically the same as on the previous flight. Lower-instrumentation panel temperatures (see Appendix A-10) averaged 20°F higher than on Flight 3042. Maximum temperature was 65°F, the average float reading was about 50°F. This temperature comparison provided an indication of the effect that the white sun shield has on the instrument container. From the data it can be concluded that the shield is no longer required over the revised lower panel on flights at this altitude. The shield will, however, be used on the 120,000 ft balloon system because of the reduced heat dissipation at the higher altitude.

2.3 Flight 3044

2.3.1 Flight Preparation

Plans were made to fly this flight at 120,000 ft altitude. Equipment was similar to that used on the previous two flights with the exception of a different altitude sensor and the addition of two sun shields. A Litton model B-58 altitude transmitter (the same unit used on Flight 3037, the 120,000 ft flight last year) was calibrated for this flight. This unit is used on flights at this altitude because it is capable of high resolution at extreme altitude. Variations in pressure-altitude as small as 100 ft at 120,000 ft are readable using this unit. The B-58 contains an internal cycle switch and was wired to provide a transmitter off time of 20 sec every 80 sec throughout the flight.

A special sun shield was devised for the top mounted payload on this flight for the purpose of reducing temperatures within the instrumentation boxes. A 21-inch diameter aluminum disc was cut into two half-moon sections with louvers cut into each section. The sections were painted a flat white color on top and flat black underneath. The sections were mounted on the solar tracker base plate so that each section completely shaded an instrument container. The white top color was selected to reflect solar heat while the louvers and the black underside coloring should remove heat from the higher temperature boxes below. The plywood mounting disc normally colored gray, was also repainted white. The white cardboard sun shield over the lower instrument gondola was again flown on this flight.

All instrumentation was set up and calibrated without change from the previous flight. The primary temperature reference resistor was connected to replace the thermistor flown on the previous two flights.

2.3.2 Field Operation

2.3.2.1 Launch

Flight 3044 was scheduled for 1 August 1967. The flight was cancelled two consecutive days due to a forecast of poor weather. On 3 August the forecast was good and the flight crew was called at the usual time. Wind velocity was 12 mph at the launch site and did not diminish during the pre-flight preparation. Further weather checks were made and the flight cancelled at 06:30 CDT due to high wind velocity. Subsequent weather checking revealed that a front through the area caused the wind at the launch site but resulted in near calm conditions only 20 miles to the south. On 4 August a favorable forecast was received and launch preparations restarted. Wind was 5 mph at 06:00 as balloon layout began. By the time the system checkout was completed and inflation was to begin, the wind had increased to a gusty 11 mph. The decision was made to proceed and inflation was completed successfully by 07:55. Wind velocity did not lessen but the final checkout indicated that all portions of the system were operating properly. Launch was smoothly accomplished at 08:04 in winds of 8 to 11 mph.

2.3.2.2 Tracking and Recovery

This flight covered three states before it was completed. The ascent course was to the southeast until 70,000 ft over a point 7 miles southeast of Ellsworth, Wisconsin. The upper winds moved the balloon west to a point 2 miles southeast of Rosemount, Minnesota at 10:40 CDT, the beginning of float. The system continued generally westward across Minnesota and about 55 miles into South Dakota by the end of the float period. The descending balloon continued west another 75 miles to a position 12 miles southwest of Miller, South Dakota at 17:40. From there the balloon system moved east and then south to impact 9 miles southwest of Woonsocket, South Dakota at 19:20 CDT.

The impact area was an open pasture. The destruct cord did not actuate but the wind was light and the gondola did not drag. The recovery crew was at the site within five minutes, and observed the large balloon layover. The balloon bubble had very little helium entrapped and the solar tracker was found upright and undamaged, folded within the deflated bubble. The lower payload was tipped on its side but undamaged. The recovery crew returned the equipment to Minneapolis the following day.

2.3.3 Flight Results

2.3.3.1 Balloon

The 200-ft diameter balloon ascended at an average rate of 782 fpm to 110,000 ft where a timed 2 percent ballast drop was initiated. The ballast caused only a slight increase in rate of rise. Overall average rate of rise was 759 fpm to float using 9 percent free lift at liftoff. Maximum altitude attained was 121,400 ft; minimum altitude was 118,500 ft during the float period. The flight was above the 114,000 ft minimum level for five hours and three minutes. This balloon was similar in design to the one used in 1966 on Flight 3037. A specification sheet and load-altitude curve of the balloon are contained in the Appendix, A-3 and A-4.

20

The balloon destruct device did not actuate due to a break in the explosive cord circuit just below the actuating squib. This break was undoubtedly caused by high wind velocity during inflation. The balloon bubble was buffeted and whipped by the unexpected wind during inflation but fortunately suffered no catastrophic damage.

2.3.3.2 Instrumentation

The suntracker, data cycling switch, telemetry transmitter, voltage reference circuitry and other primary components of the system performed properly throughout the flight. Despite the precautions taken before this flight program and despite the fact that there was no interference on the first two flights, data interference was a problem on this flight. The noise or radio-frequency interference was apparent on ascent and during the entire float period on data channels 18, 19, 21 and 22 only. The interference, as seen on both the analog and digital data recordings, correlated with the on-off keying of the B-58 altitude transmitter. The interference was continuous except when the 20-second off period of the B-58 occurred with the data commutator on the four affected channels. Digital data recording affected by this interference was marked and can be disregarded during data reduction. There should be a sufficient number of good readings, recorded when the interferring transmitter was off, to provide an accurate record of solar cell output during the float period. The temperature telemetry and reference voltages were not affected. The reference frequencies did not vary more than plus or minus two Hertz from their nominal frequency during the floating period.

Comparisons of secondary telemetry and lower-instrumentation temperatures recorded on this flight and those from Flight 3037 show that the comparative data stability was improved because lower and more stable temperatures were maintained within the system. Appendix A-8 shows the maximum Box #1 and #2 temperatures to be +42°C and +48°C, respectively. On Flight 3037 the maximum temperatures were +67°C and +55°C, respectively. Appendix A-10 shows that the lower-instrumentation temperatures averaged a very stable +41°F through the float period. On Flight 3037 this section reached +100°F during float and increased to a maximum of +125°F during descent. Interestingly, the tracker mounted thermistor indicated a higher maximum reading on this flight (+65°C) than on Flight 3037 (+54°C). In contrast, the white tracker mounting disc reached a maximum of only +33°C compared to the gray disc maximum of 60°C on the previous 120,000 ft flight. This data indicates that although ambient temperature at the tracker was higher than on Flight 3037, the painting, shielding and redesign preceding the flight was effective in temperature stabilizing the electronic systems.

2.4 Flight 3045

2.4.1 Flight Preparations

System components were not damaged on the previous flight. Except for the B-58 altitude sensor and the ballast drop controls, the same components were recalibrated for use on this flight. The B-58 was replaced by the originally used low range altitude beacon including the float cut-off timer as flown on all 80,000 ft flights since 1966. The solar tracker, on-sun circuit, modulation levels and secondary temperature circuits required no adjustments from previous calibrations. Appendix A-5 shows the primary reference voltages to be very close to previous data and not requiring readjustment. An on-sun test of the entire system, including the balloon and parachute cables to be flown, was conducted at the launch site and the equipment was judged ready to fly.

2.4.2 Field Operation

2.4.2.1 Launch

Launch preparations for Flight 3045 began on schedule on 10 August 1967. Instrumentation checkout and system layout proceeded on schedule. Inflation began at 08:10 CDT with wind 2 mph out of the northeast. Inflation was finished at 08:35. The system was released at 08:46 in light and variable wind conditions. The launch situation was similar to Flight 3043 when a rough release was experienced. This time, however, the launch vehicle turned sharply with the wind as the balloon bubble was released and the gondola release was precisely timed so that the system experienced no shock and ascended cleanly away from the launch frame.

2.4.2.2 Tracking and Recovery

The balloon system ascended slowly to the southeast. Over Millville, Minnesota at 70,000 ft, the system turned westward. For the remaining ascent period and during the float period the system moved west to a point approximately 5 miles south of Faribault, Minnesota at the initiation of descent. The descending balloon moved south to impact 10 miles northwest of Austin, Minnesota at 17:03 CDT.

The lower payload touched down in an alfalfa field and although the destruct device actuated on impact the gondola was dragged about 30 yards to a barbed wire fence where the balloon and tracker laid over into a soybean field. Actual damage to the property and crops was minor. The equipment (solar cells, sun tracker and instrumentation, except for the parachute which was ripped on the fence) again suffered no damage. The recovery crew was able to load the equipment, clean up the area, discuss damages with the property owner and return to the plant that evening without incident.

2.4.3 Flight Results

2.4.3.1 Balloon

The balloon design and material was identical to that used on all 80,000 ft flights during the last two years. The required amount of helium was calculated (gross system weight plus 8 percent) and this amount used to fill the balloon bubble in the usual manner. The rate of rise was 500 fpm to 45,000 ft and 266 fpm from there to float, an overall rate of rise of only 364 fpm. The system did not reach the 76,000 ft level until 12:07 CDT and remained above that level only three hours and eight minutes. Maximum altitude was 80,000 ft and the minimum reading was 79,500 ft during the actual balloon floating period.

The cause of the slow ascent and resulting reduction in float time was investigated the following day. Helium calculations were triple checked and determined correct. Each of the thirty high-pressure tubes on the helium trailer used were rechecked for pressure without finding any discrepancy. A day later the helium trailer was tested again. At this time a faint hissing sound was heard coming from a fitting used to couple the tubes to the pressure gage and to a common outlet. A pinhole leak was found in this fitting. It is estimated that the amount of helium lost through this hole reduced the available system free lift from the desired 8 percent to approximately 4 percent. This would explain the slow ascent rate.

2.4.3.2 Instrumentation

All telemetered data was exceptionally stable on this flight. Reference frequencies were again within two Hertz of their nominal frequency throughout the float. Radio noise interference was not a problem this time. Two minor telemetry problems were noted during the flight. As the flight progressed and the data was reviewed, it was noticed that the solar cell thermistor channel (#20) was indicating a constant reading although the actual temperature at that point would normally not be constant. The reading corresponded to an open circuit frequency; post flight investigation revealed a broken thermistor lead at the connection terminal. The second discrepancy was excessive drift in the data recorded by the analog recorder. The variation was not noticed in the primary digital record and thus was isolated at either the frequency discriminator or the analog recorder. The problem did not continue but both instruments will be carefully checked before any future flights.

3.0 CONCLUSIONS

Major objectives of this program were accomplished. The four flights attempted this year were successful in that each balloon reached its expected altitude, the suntrackers and telemetry system operated continuously throughout each flight, and all equipment and solar cells were recovered without major problems. This is the third consecutive yearly program for Jet Propulsion Laboratories that has achieved 100 percent balloon success (4 flights out of 4 attempts).

The modifications made to the airborne system during the program were highly successful. The new power supply, solar tracker clutch, solid-state data switch driver, revised lower instrument panel, and top sun shield all helped to significantly increase reliability, accuracy, and stability. Specifically, the lighter weight of the power supply allowed all flights to reach the design altitude; the solar tracker clutch reduced repair and check-out time between flights and reduced the possibility of an off-sun lockup during the flights; the solid-state driver improved reliability by elimination of several mechanical devices and improved telemetry data accuracy and stability by reducing heat dissipation; the revised instrument panel and added sun shield also potentially improved data accuracy and stability by stabilizing airborne system temperatures.

Two discrepancies occurred during the program. Although all telemetry channels were free of interference on the three 80,000 ft flights, radio frequency noise was encountered on four data channels on the single 120,000 ft flight (#3044). The source of the interference is known to be the altitude transmitter, but just how the interference affects certain data channels is not known. To eliminate this problem in the future, if the same altitude sensor is used, the sensor will be programmed to provide only a short transmit time with a comparatively long off time. Regardless of the altitude sensor used, a turn off circuit will be routinely flown on all flights to insure sufficient noise-free data.

The second discrepancy occurred on the final flight when the rate of balloon rise was less than one-half the normal rate, resulting in a loss of about 28 percent of the desired floating time. A small leak through a weld on a helium pressure fitting between the trailer plumbing and the inflation hose, accounted for the approximately 4 percent loss in free lift. This is not likely to occur again; nevertheless, the inflation system will be carefully checked preceding all future flights.

Despite the problems discussed, this series of flights was better in all respects than any previous program. Instrumentation reliability and data stability were outstanding factors during this year's operation.

4.0 RECOMMENDATIONS

Although the flight operations have been very successful for the past three years, there is always room for improvement in reliability and/or cost reductions. In addition, there are many possible system modifications that could produce, at low cost, increased test capacity; stable test temperatures, or significant improvement in data reduction effort.

The two solar trackers presently used on this program were not damaged this year and thus are still usable for future flights. Test capacity of these units could be expanded considerably by using a solar cell mounting plate with an area two to four times greater than the present design. The modification would involve remounting the shade seeking photodiodes, separating and adding terminals for additional signal wiring, and selecting and wiring a stepping switch capable of handling the added data channels. The present Box #1 connector has only six extra connector pins while the tracker has twelve available pins. By adding another connector to Box #1 the system could be expanded by twelve channels to a total of 36 channels, including 26 solar cell output channels. Stepping switches with 36 points are commonly available and will fit the available space but they are normally long-delivery items.

To simplify data reduction, a simple modification can be added to the ground station digital recorder. This modification would disable the electronic counter and printer during the switching time and allow a single reading to be printed only in the middle of the data sequence. Thus there would be, for example, 24 readings for the 24 steps. This would eliminate much of the human interpretation of the data now required. The on-board switching time-base is stable enough so that a synchronizing signal from the payload would not be required. The circuitry would consist of a 13-second time delay capable of disabling the counter/printer. A pulse from the counter would be used to reset the delay after one count. Synchronization would be accomplished manually at the start and up-dated as required.

The digital data could be put into computer input form directly but the method of accomplishing this is not simple. One method requires an accurate analog to binary converter and an automatic paper-tape punch. The flight data could be sequentially coded on the tape and inserted into a properly programmed computer at comparatively high speed. Frequency counters are commonly available with binary coded outputs; an automatic paper tape punch may operate directly from this type of counter. This division does not have the paper tape equipment to accomplish this task; JPL-supplied equipment could be incorporated into the present ground station to convert the data directly into computer input form. An automatic system of this type would save countless data reduction man-hours.

A major improvement in data stability could be obtained if the solar cell temperatures were held constant throughout the float period. In fact, the float period could probably be shortened under these conditions. Initially, thermoelectric cooling was considered, but the high power required is not practical with the present configuration. A much better way to maintain stable solar cell temperatures would be to use a fluid boil-off system. That is, a fluid would be selected that changes state (from liquid to vapor) at or near the desired control temperature at the absolute pressure encountered at the float altitude. This fluid would be in thermal contact with the solar cell mounting plate so that as the plate was heated by solar energy to a temperature above the control point, the fluid would vaporize and be vented to the atmosphere. Since the heat of vaporization of the fluid is a constant and since the mounting plate would be in good thermal contact with the fluid, the mounting plate temperature would be held practically constant as long as the solar heating was greater than the control temperature and as long as the supply of fluid was maintained.

Hardware necessary to accomplish this task should not be very complicated. In its simplest form, the system would consist of a liquid container with a non-spill vent. The container would be mounted between the tracker mechanism and the solar cell mounting plate. It would be insulated from the mechanism but be in very good thermal contact with the plate. The necessary capacity of the tank is not known, but can be estimated with the temperature data available. The design in a more sophisticated form may involve an auxiliary tank, a pressure tank, an automatic valve and a pressure regulator. Litton's current experience in balloon-borne air samplers powered by liquid/gas propellants would lend itself to a design of this type.

The Applied Science Division of Litton looks forward to another opportunity to satisfy the requirements of Jet Propulsion Laboratory in the areas of high performance airborne mechanical, fluidic and electronic systems and balloon operations.

5.0 NEW TECHNOLOGY

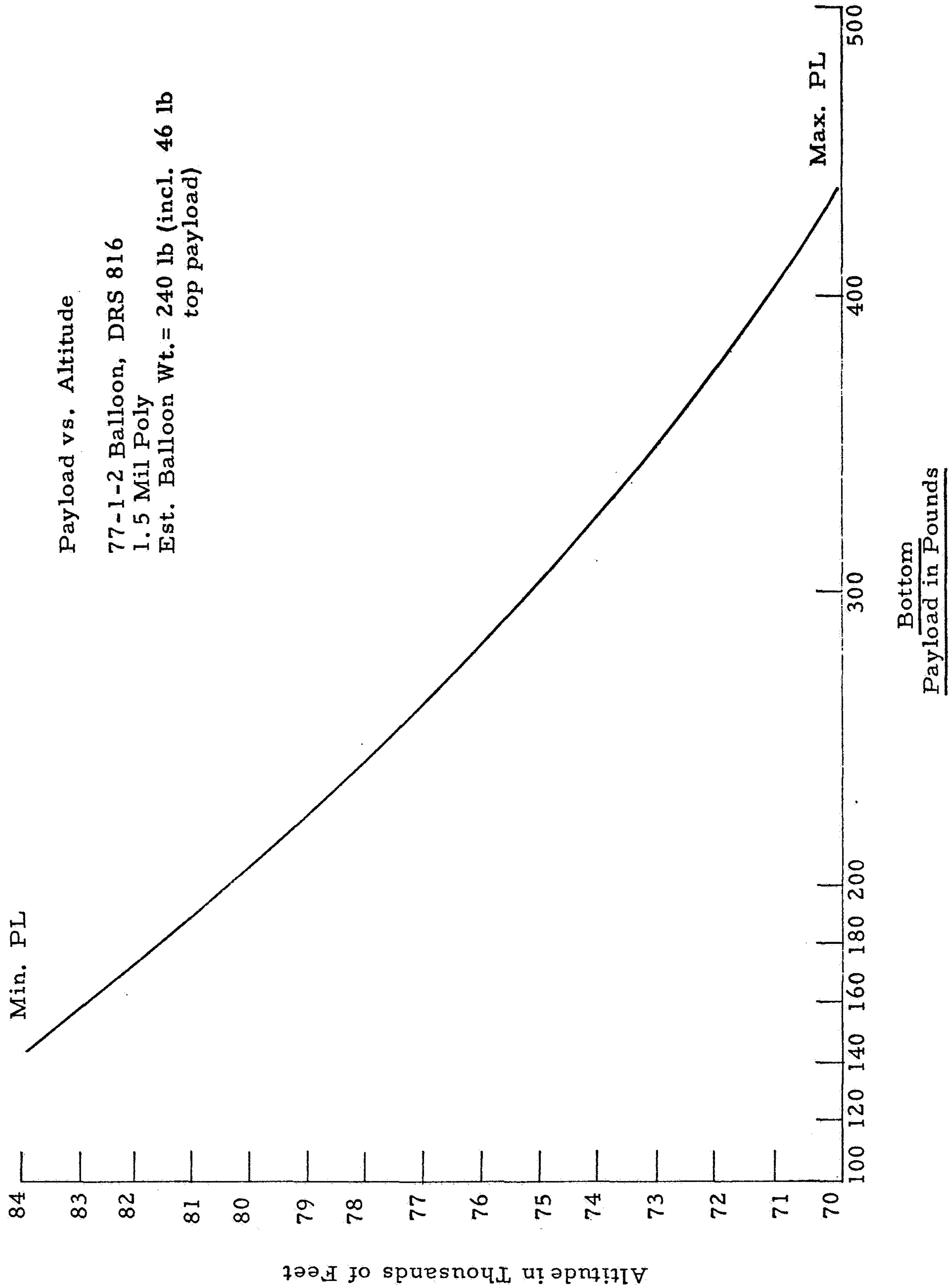
No items of new technology have been identified or reported during the course of this contract.

APPENDIX

Flight Data

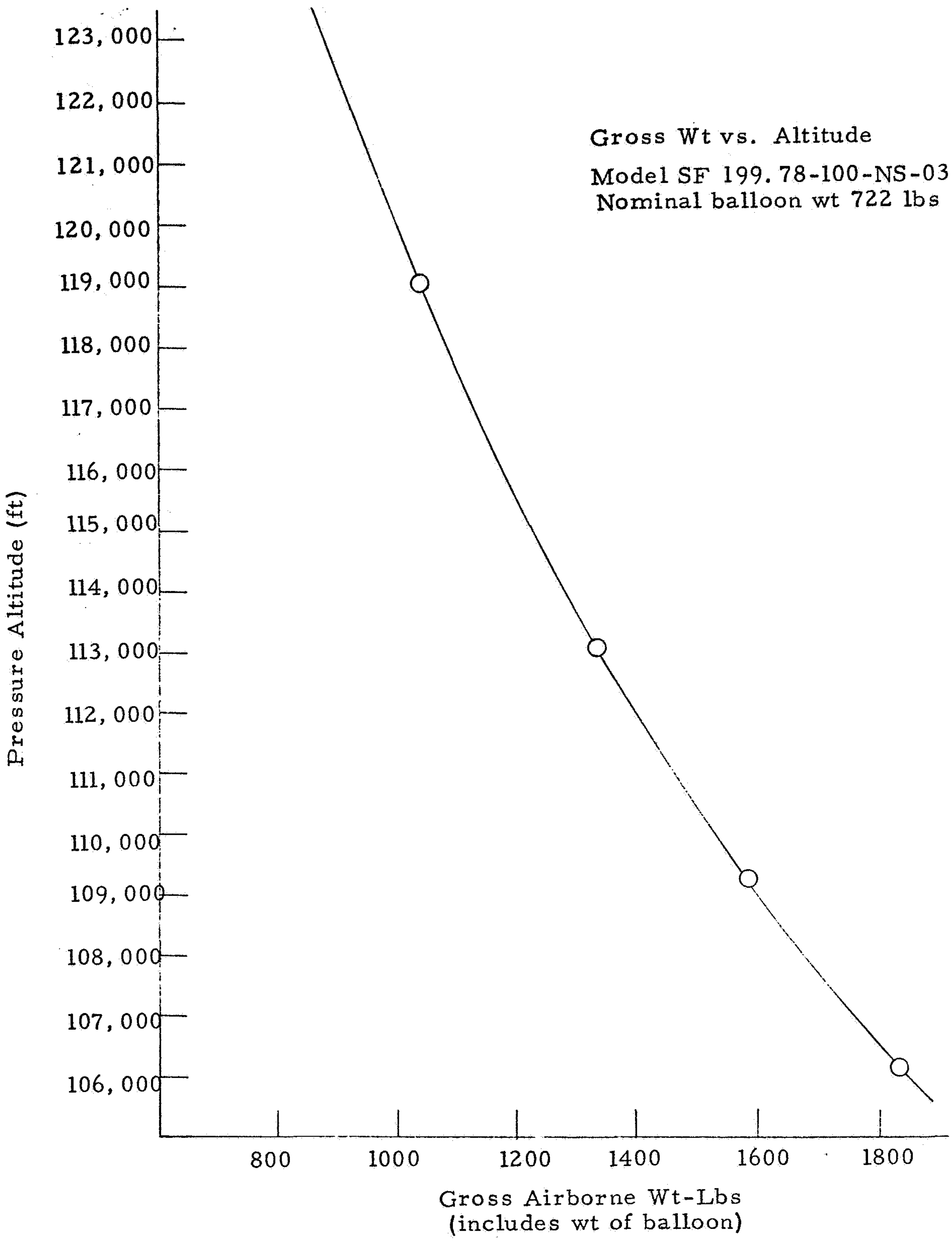
Operational Specification Sheet
(for 77-1-2 balloon)

Fabric Parameter (Σ) -	0.05
Payload (Design) -	219 lb 46 lb Top PL
Material (Balloon Wall and Duct) - - - - - - - - - - - - -	1.5 mil Polyethylene
Volume (Theoretical) -	189,113 ft^3
Surface Area (Estimated) - - - - - - - - - - - - - - - - - -	15,996 ft^2
Inflated Height -	86.25 ft
Deflated Length (Gore Length) - - - - - - - - - - - - - - -	113.5 ft
Load Tapes -	None
Fittings; top -	Inverted EV-13, 230822
Fittings; bottom -	4 in. diameter integral
Number of Ducts -	Two
Location of Duct - - - - - - 10 sq ft each Lo-Duct	40 ft from base
Hi-Duct	35 ft 6 in from top apex
Inflation Tube -	20 in. layflat x 3 mil x 75 ft long
Inflation Attachment -	20 ft from top apex, 233399
Destruction Device -	Prima Cord
Descent Valves -	One located 34 ft 6 in. from top apex
Estimated Balloon Weight - - - - - - - - - - - - - - - - -	185 lb (incl. 25 lb of cable)
Engineering Specification Sheet - - - - - - - - - - - - -	234654
DRS -	816
Load Altitude Curve -	233521


Payload vs. Altitude
77-1-2 Balloon, DRS 816
1.5 Mil Poly
Est. Balloon Wt.= 240 lb (incl. 46 lb top payload)
Min. PL
Max. PL
Bottom Payload in Pounds
Altitude in Thousands of Feet
100 120 140 160 180 200 300 400 500
70 71 72 73 74 75 76 77 78 79 80 81 82 83 84

Operation Specification Sheet
(for SF-199.78-100-NS-03 balloon)

Fabric Parameter (Σ)	0.40
Payload (Design)	245 lb to 120,000 ft.
Material (Balloon Wall and Duct)	1.0 mil S. F. Polyethylene
Volume (Theoretical)	2,940,000 ft^3
Surface Area (Estimated)	Not Available
Inflated Height	152 ft
Deflated Length (Gore Length)	271 ft
Load Tapes	300 lb
Fittings; top	Plate Hoop and Ring-21 in. I.D.
Fittings; bottom	4 in. I.D. Wedges and Collar
Number of Ducts	Three
Location of Duct - 25 sq ft each; Lo-Duct(2)	100 ft from base
Location of Duct - 25 sq ft each; Hi-Duct	235 ft from base
Inflation Tube	20 in. layflat x 3 mil x 85 ft long
Inflation Attachment	30 ft from top apex
Destruction Device	Prima Cord
Descent Valves	Three in hi-duct
Estimated Balloon Weight	755 lb (incl. cable)
Engineering Specification	CO 1326
DRS	248
Load Altitude Curve	100381


Gross Wt vs. Altitude
Model SF 199.78-100-NS-03
Nominal balloon wt 722 lbs
Pressure Altitude (ft)
123,000
122,000
121,000
120,000
119,000
118,000
117,000
116,000
115,000
114,000
113,000
112,000
111,000
110,000
109,000
108,000
107,000
106,000
800
1000
1200
1400
1600
1800
Gross Airborne Wt-Lbs
(includes wt of balloon)

32

Final System Calibration Data

Reference Calibration Levels	Flight 3042 Voltage (millivolts)	Flight 3042 Frequency (cycles/sec)	Flight 3043 Voltage (millivolts)	Flight 3043 Frequency (cycles/sec)	Flight 3044 Voltage (millivolts)	Flight 3044 Frequency (cycles/sec)	Flight 3045 Voltage (millivolts)	Flight 3045 Frequency (cycles/sec)
100 mv	100.006	6849	100.004	6847	100.005	6845	100.001	6848
80	80.018	7071	80.016	7070	80.016	7070	80.012	7071
70	70.013	7183	70.010	7181	70.007	7180	70.006	7182
60	60.000	7293	60.000	7292	59.995	7290	59.995	7293
50	50.001	7402	49.999	7401	49.998	7400	50.000	7402
25	24.966	7673	24.966	7672	24.966	7671	24.966	7673
0	00.001	7939	00.000	7938	00.001	7938	00.001	7939

Telemetered Secondary Temperature Data; Flight 3042, 14 July 1967

Time From Launch	Temperature (in degrees C)				
	V. C. O.	Disc	Box #1	Tracker	Box #2
L-1/2 hr	+48	+16	+26	+18	+32
L (08:35 CDT)	48	17	26	18	33
L+1/2	47	-8	26	17	34
L+1	47	-34	17	0	27
L+1-1/2	46	-19	17	3	22
L+2	47	1	17	17	29
L+2-1/2	47	10	20	21	33
L+3	47	4	26	28	35
L+3-1/2	48	7	32	31	36
L+4	48	4	29	32	40
L+4-1/2	49	2	35	36	42
L+5	49	-2	37	36	42
L+5-1/2	49	0	37	36	42
L+6	49	7	34	36	45
L+6-1/2	49	13	34	37	47
L+7	49	-16	31	32	45
L+7-1/2	49	-35	26	12	41
L+8	+47	-25	+14	-12	+26

Telemetered Secondary Temperature Data; Flight 3043, 25 July 1967

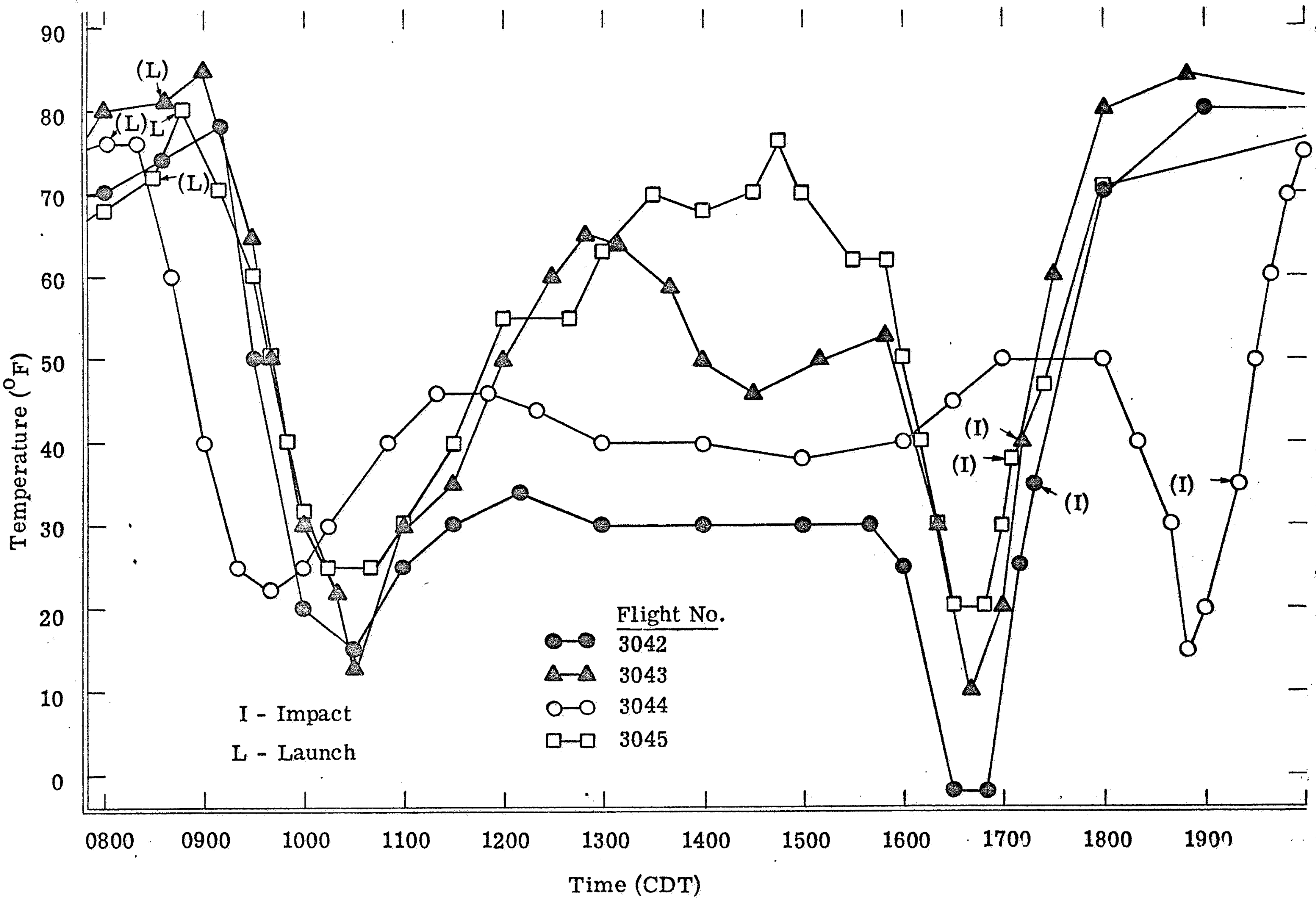
Time From Launch	Temperatures (in degrees C)				
	V. C. O.	Disc	Box #1	Tracker	Box #2
L-1/2 hr	+49	+21	+33	+27	+39
L (08:37 CDT)	49	22	35	28	39
L+1/2	49	-2	31	22	37
L+1	49	-31	22	7	33
L+1-1/2	47	-30	15	-1	26
L+2	47	-15	15	6	26
L+2-1/2	48	4	19	18	31
L+3	48	3	19	18	31
L+3-1/2	48	5	32	28	31
L+4	48	4	31	29	34
L+4-1/2	49	5	29	30	37
L+5	49	7	29	32	42
L+5-1/2	50	6	29	35	47
L+6	50	12	30	35	48
L+6-1/2	49	1	36	34	42
L+7	49	-17	34	27	40
L+7-1/2	48	-41	23	5	36
L+8	47	-18	15	-11	23
L+8-1/2	+48	+22	+21	+14	+26

Telemetered Secondary Temperature Data; Flight 3044, 4 August 1967

Time From Launch	Temperatures (in degrees C)				
	V. C. O.	Disc	Box #1	Tracker	Box #2
L-1/2 hr	+47	+14	+25	+15	+29
L (08:04 CDT)	47	11	25	17	31
L+1/2	47	-25	22	12	30
L+1	47	-36	14	-4	25
L+1-1/2	46	-21	11	0	22
L+2	47	-4	13	11	22
L+2-1/2	47	9	19	23	26
L+3	47	17	23	36	32
L+3-1/2	49	30	27	48	36
L+4	49	32	30	55	40
L+4-1/2	49	30	33	57	44
L+5	49	33	36	65	45
L+5-1/2	49	32	37	62	47
L+6	49	31	40	62	47
L+6-1/2	50	23	40	65	48
L+7	48	19	42	55	44
L+7-1/2	49	22	42	55	44
L+8	49	18	42	54	44
L+8-1/2	49	17	40	52	47
L+9	49	9	39	47	45
L+9-1/2	+49	-21	+39	+39	42

Telemetered Secondary Temperature Data; Flight 3045, 10 August 1967

Time From Launch	Temperatures (in degrees C)				
	V. C. O.	Disc	Box #1	Tracker	Box #2
L-1/2 hr	+47	+12	+25	+16	+30
L (08:46 CDT)	49	13	26	18	32
L+1/2	49	-7	24	17	33
L+1	48	-28	18	2	27
L+1-1/2	47	-21	12	-3	25
L+2	47	-12	12	1	25
L+2-1/2	47	0	15	8.5	24
L+3	47	9	21	18	26
L+3-1/2	47	22	23	25	31
L+4	48	23	29	30	34
L+4-1/2	48	25	34	34	36
L+5	48	26	34	36	39
L+5-1/2	48	25	36	36	39
L+6	48	22	37	36	40
L+6-1/2	48	15	34	34	40
L+7	48	15	34	34	40
L+7-1/2	47	-31	21	-7	28
L+8	+46	+ 1	+15	-4	+22



Payload Temperature Profiles

38

FLIGHT NO. 3042 DATE 14 July 1957

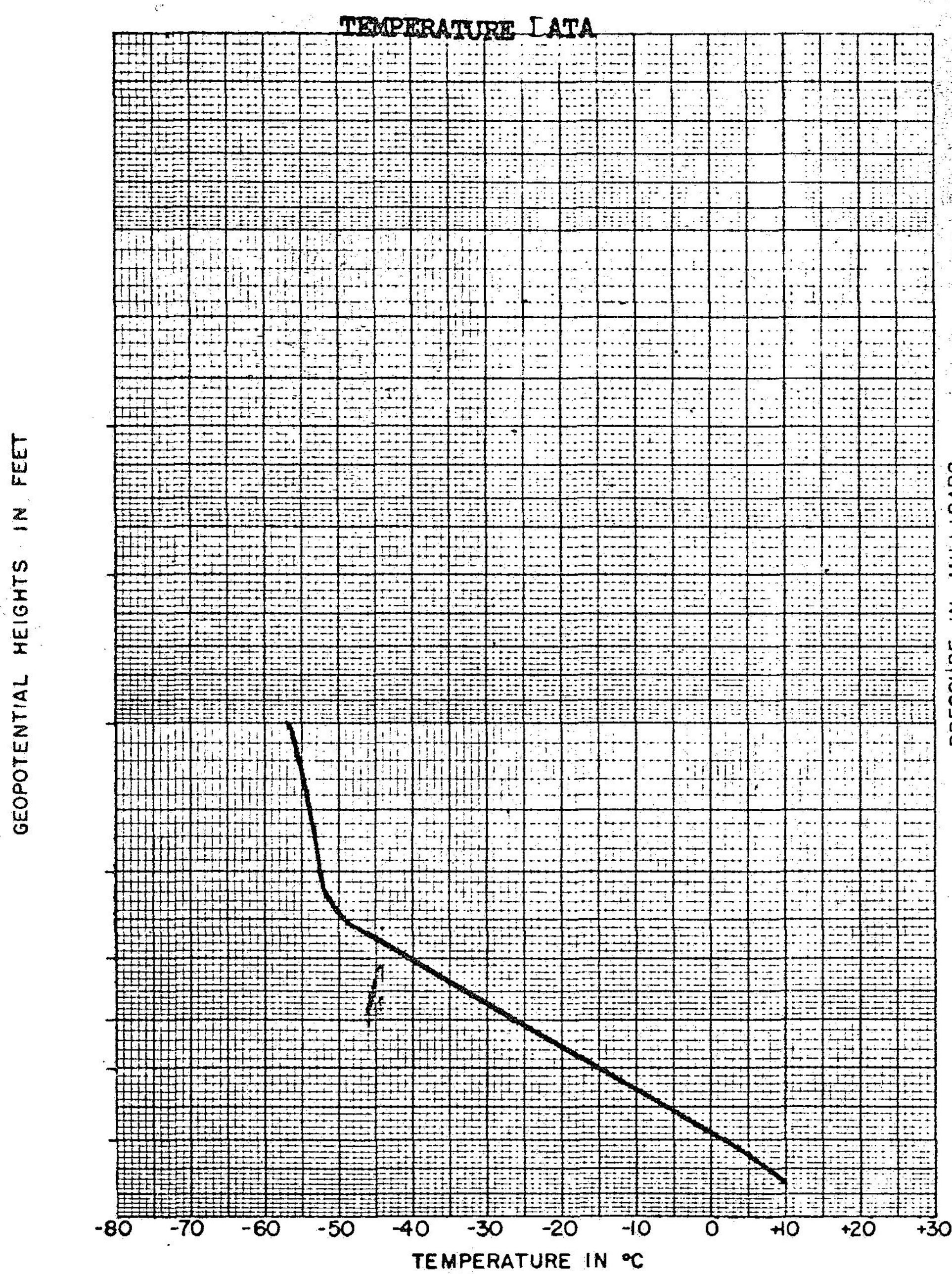
FOR JPL 59651

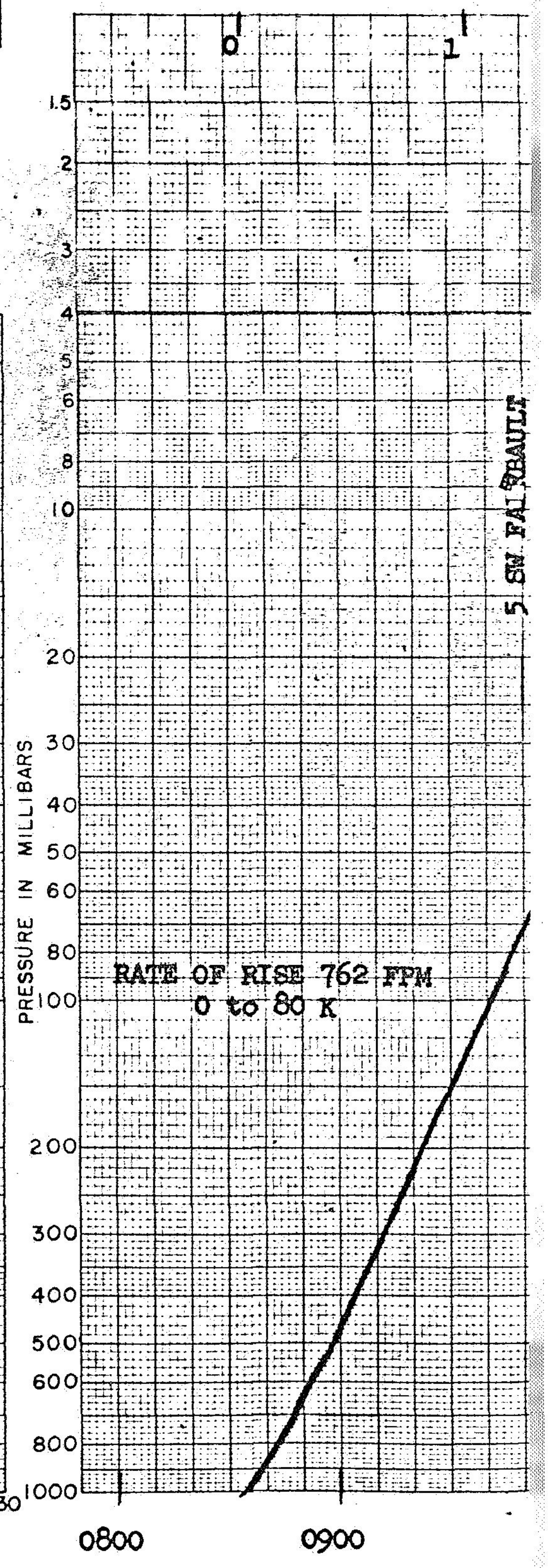
LOAD ON BALLOON 241 lbs

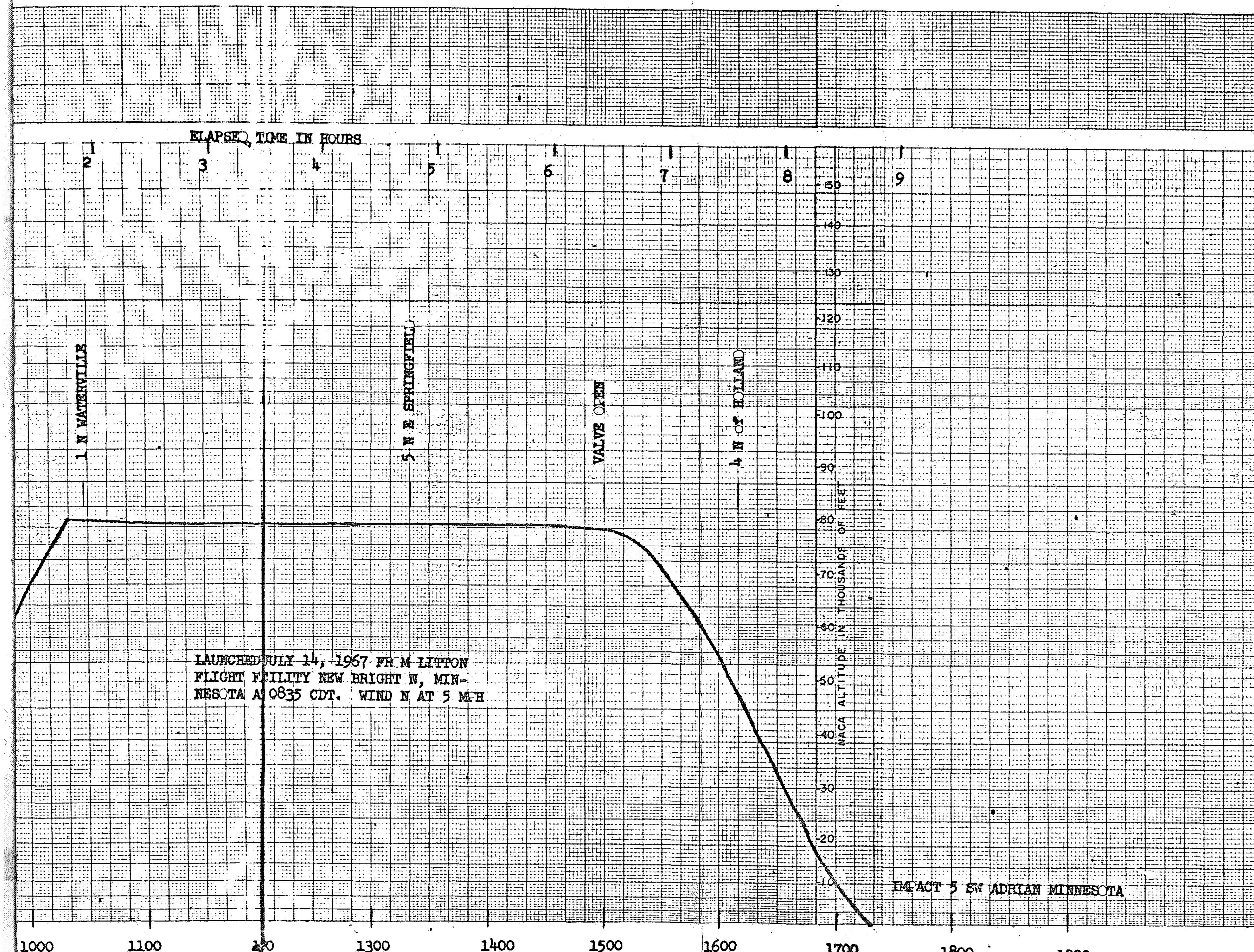
FREE LIFT 35 LBS= 8 %

BALLOON TYPE	NUMBER	MATERIAL	WEIGHT
77-1-2	1 DRS 816	1.5 MIL	197 LBS.

ALTITUDE DATA







ELAPSED TIME IN HOURS
2
3
4
5
6
7
8
9
1 N WATERVILLE
5 N E SPRINGFIELD
VALVE OPEN
4 N OF HOLLAND
LAUNCHED JULY 14, 1967 FROM LITTON
FLIGHT FACILITY NEW BRIGHTON, MIN-
NESOTA AT 0835 CDT. WIND N AT 5 MPH
IMPACT 5 SW ADRIAN MINNESOTA
NACA ALTITUDE IN THOUSANDS OF FEET
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900

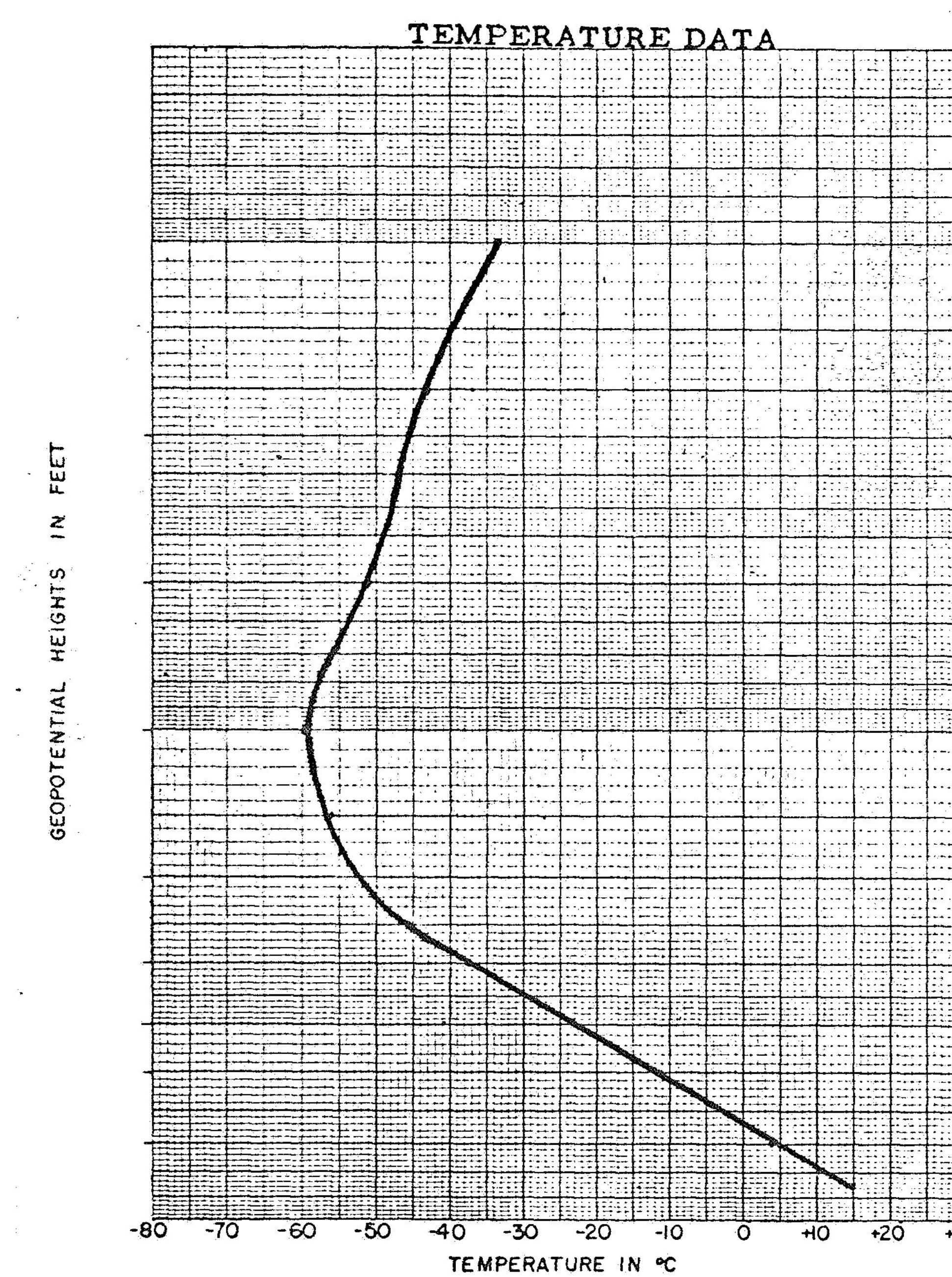
A-11

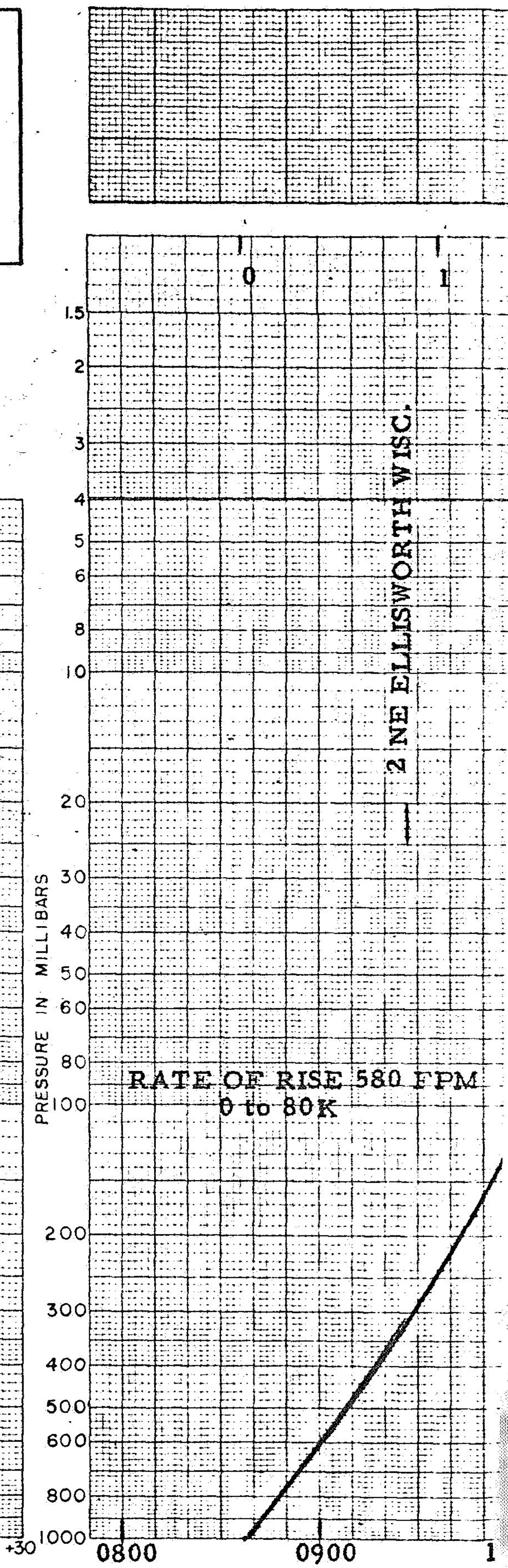
FLIGHT NO. 3043 DATE 25 July 1967
FOR JPL 59651
LOAD ON BALLOON 238 lbs
FREE LIFT 35LBS= 8 %

BALLOON TYPE	NUMBER	MATERIAL	WEIGHT
77-1-2	2 DRS 816	1.5 Mil	199.5 LBS.

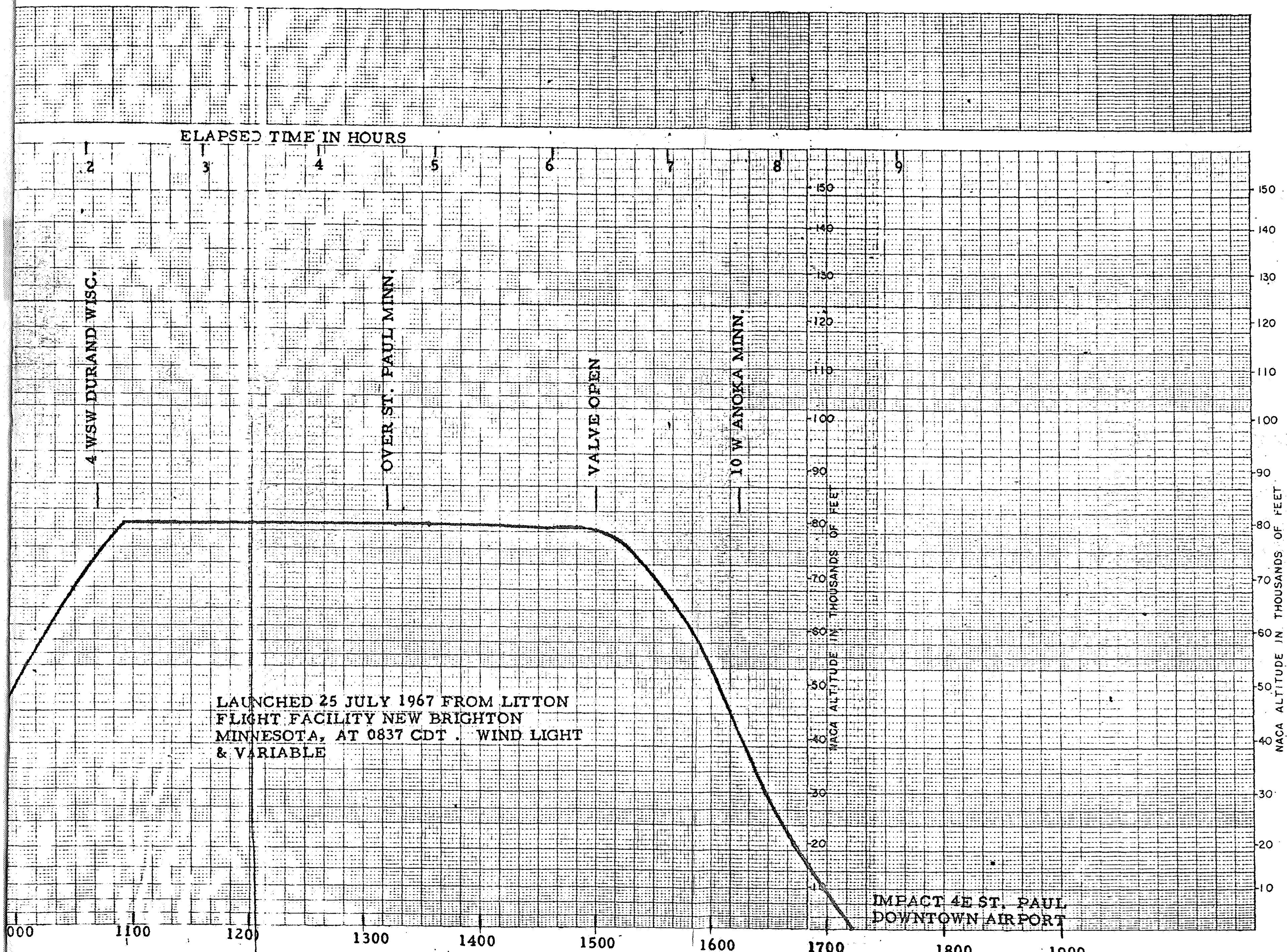
ALTITUDE DATA

TEMPERATURE DATA





0283 ED



ELAPSED TIME IN HOURS
2
3
4
5
6
7
8
9
4 WSW DURAND WISC.
OVER ST. PAUL MINN.
VALVE OPEN
10 W ANOKA MINN.
LAUNCHED 25 JULY 1967 FROM LITTON FLIGHT FACILITY NEW BRIGHTON MINNESOTA, AT 0837 CDT. WIND LIGHT & VARIABLE
IMPACT 4E ST. PAUL DOWNTOWN AIRPORT
NACA ALTITUDE IN THOUSANDS OF FEET
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900

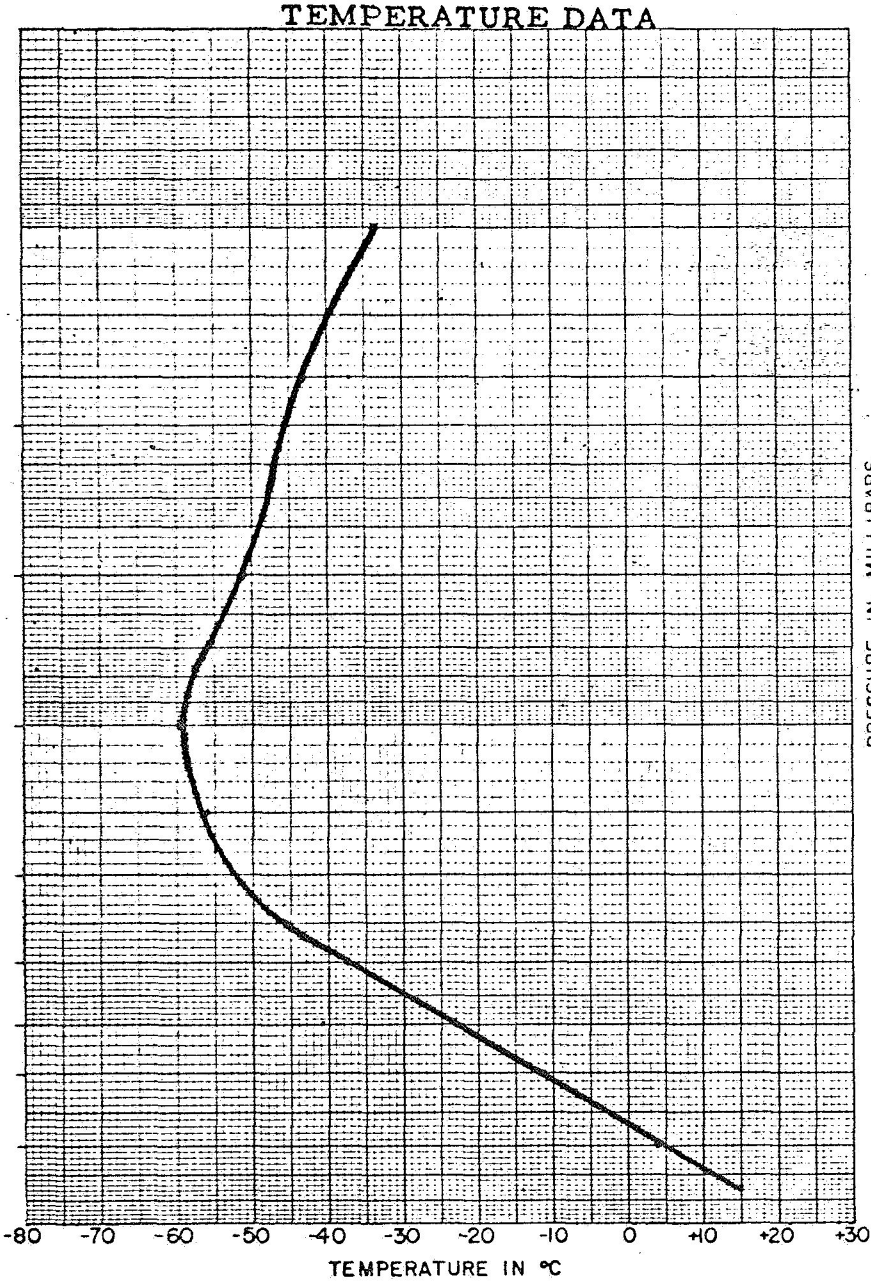
A-12

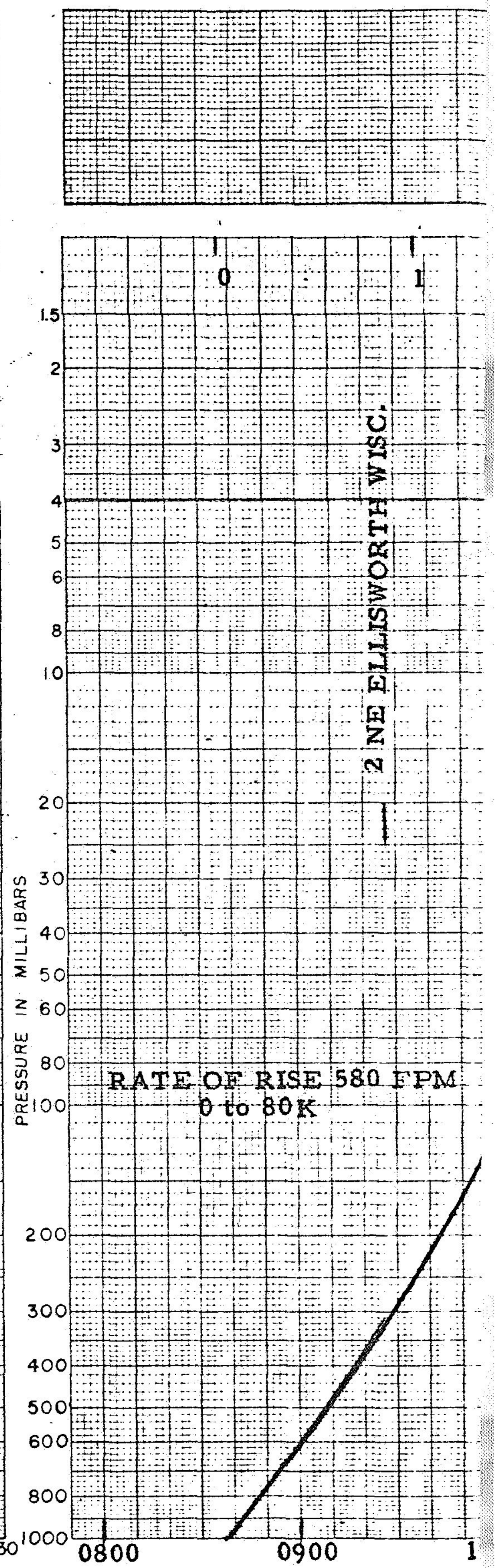
40

FLIGHT NO. 3043 DATE 25 July 1967
FOR JPL 59651
LOAD ON BALLOON 238 lbs
FREE LIFT 35LBS= 8 %

BALLOON TYPE	NUMBER	MATERIAL	WEIGHT
77-1-2	2 DRS 816	1.5 Mil	199.5LBS

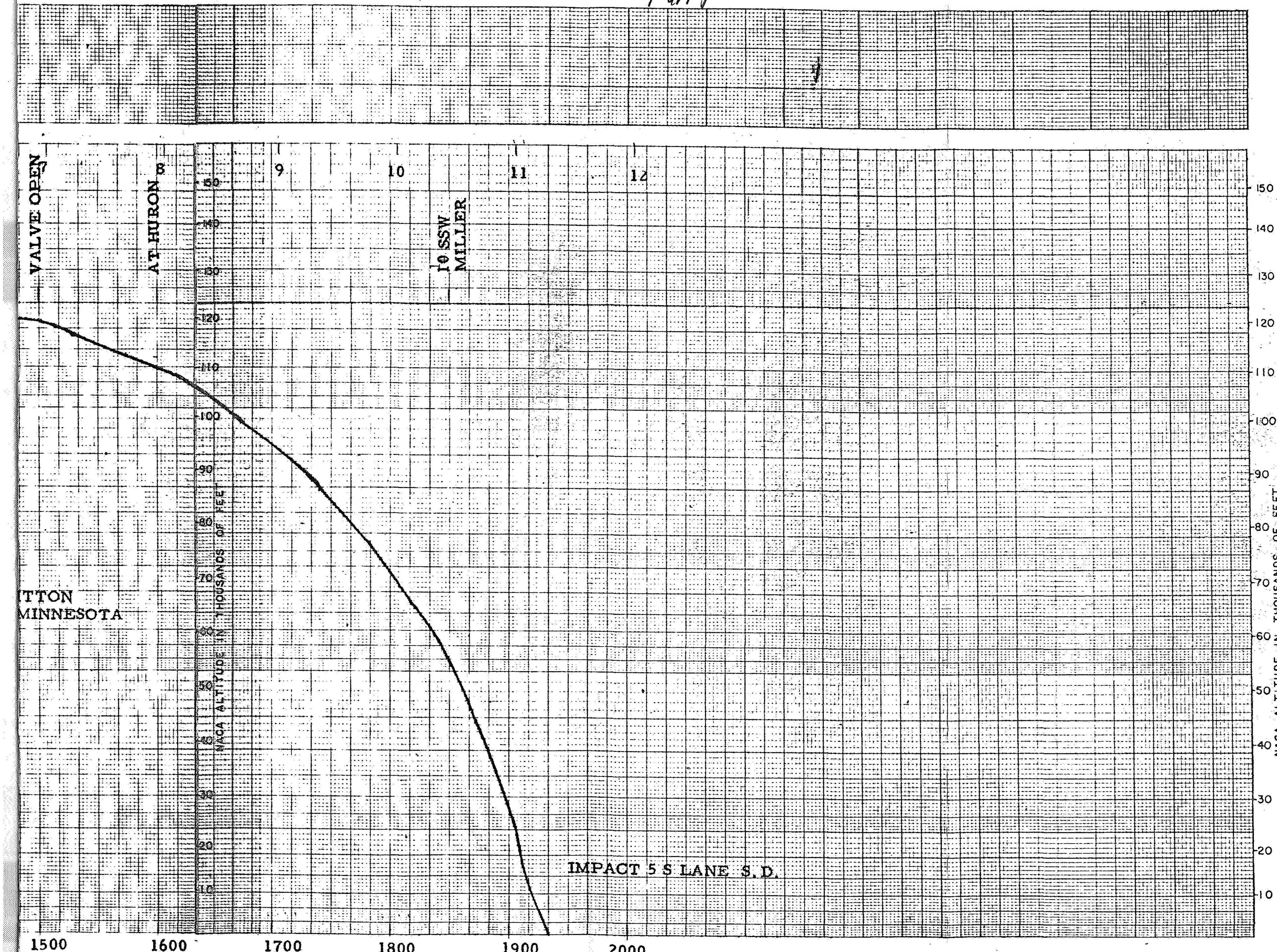
ALTITUDE DATA





0293 ED

Part I


VALVE OPEN
AT HURON
10 SSW MILLER
ITTON MINNESOTA
IMPACT 5 S LANE S.D.
NACA ALTITUDE IN THOUSANDS OF FEET
7
8
9
10
11
12
1500
1600
1700
1800
1900
2000
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10

A-13

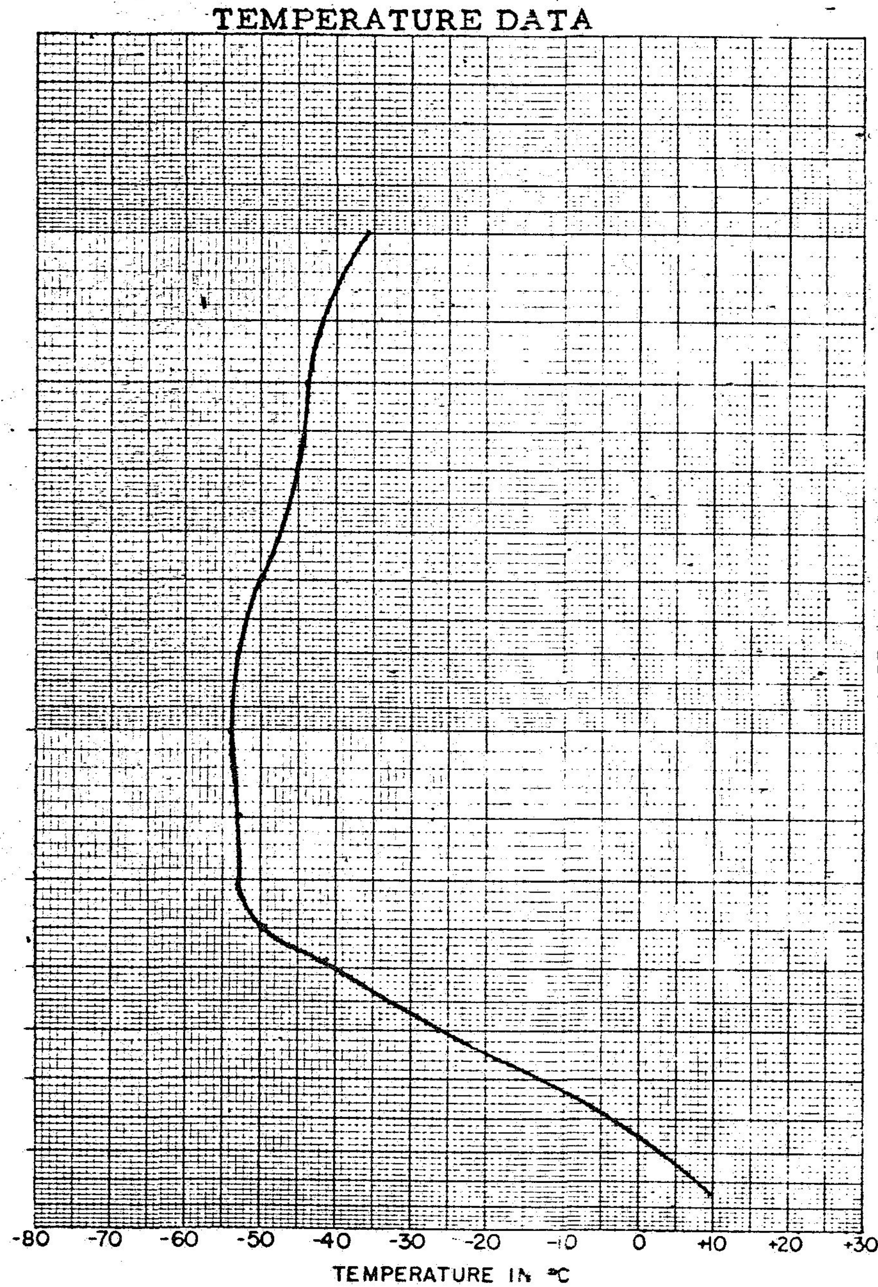
Part 2

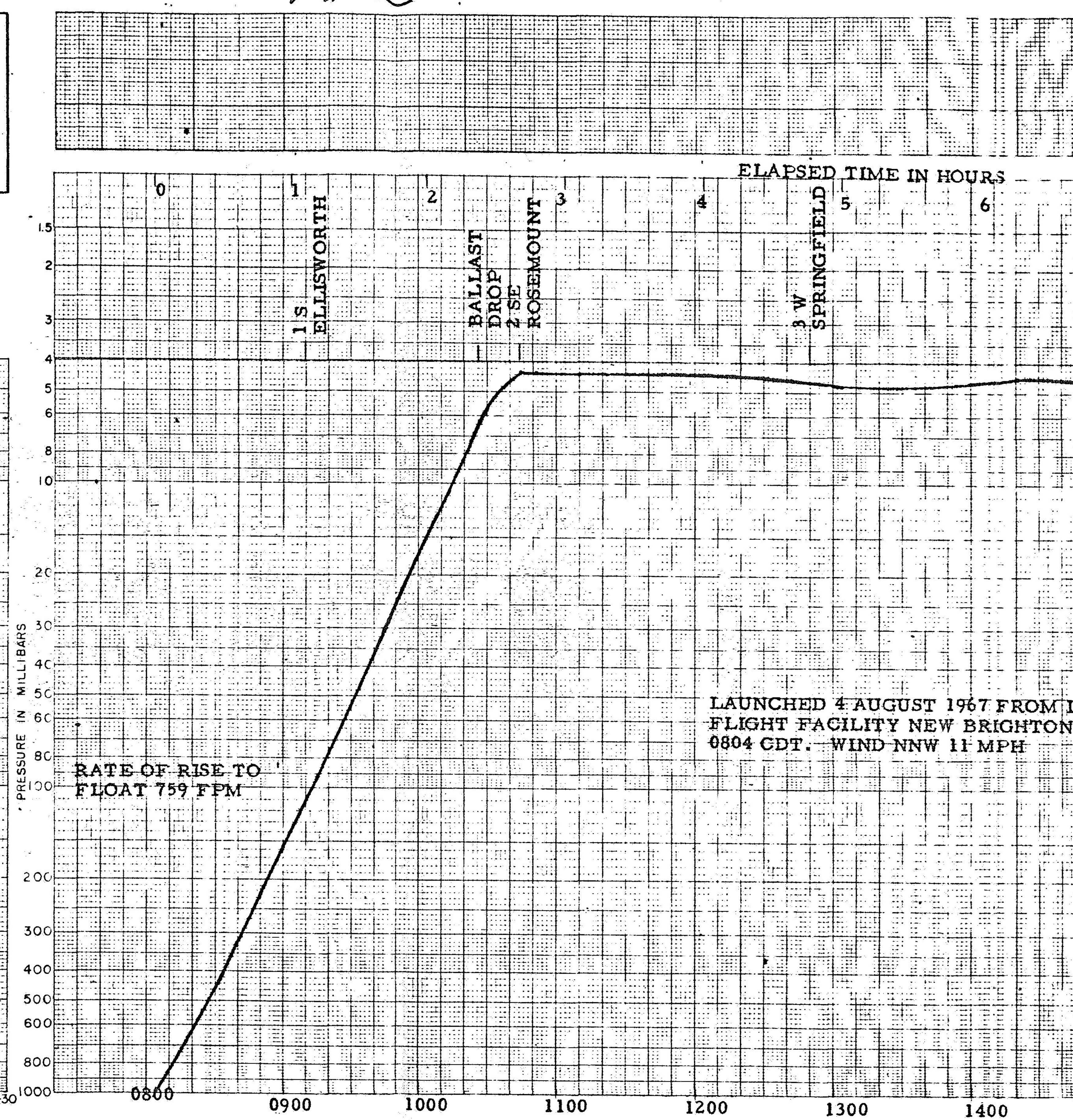
FLIGHT NO. 3044 DATE 4 August 1967
FOR JPL 59651
LOAD ON BALLOON 275 lbs
FREE LIFT 94 LBS= 9 %

BALLOON TYPE	NUMBER	MATERIAL	WEIGHT
SF-199.78-100-~~NS-03~~	248	.750 Mil	765 LBS.

ALTITUDE DATA

TEMPERATURE DATA





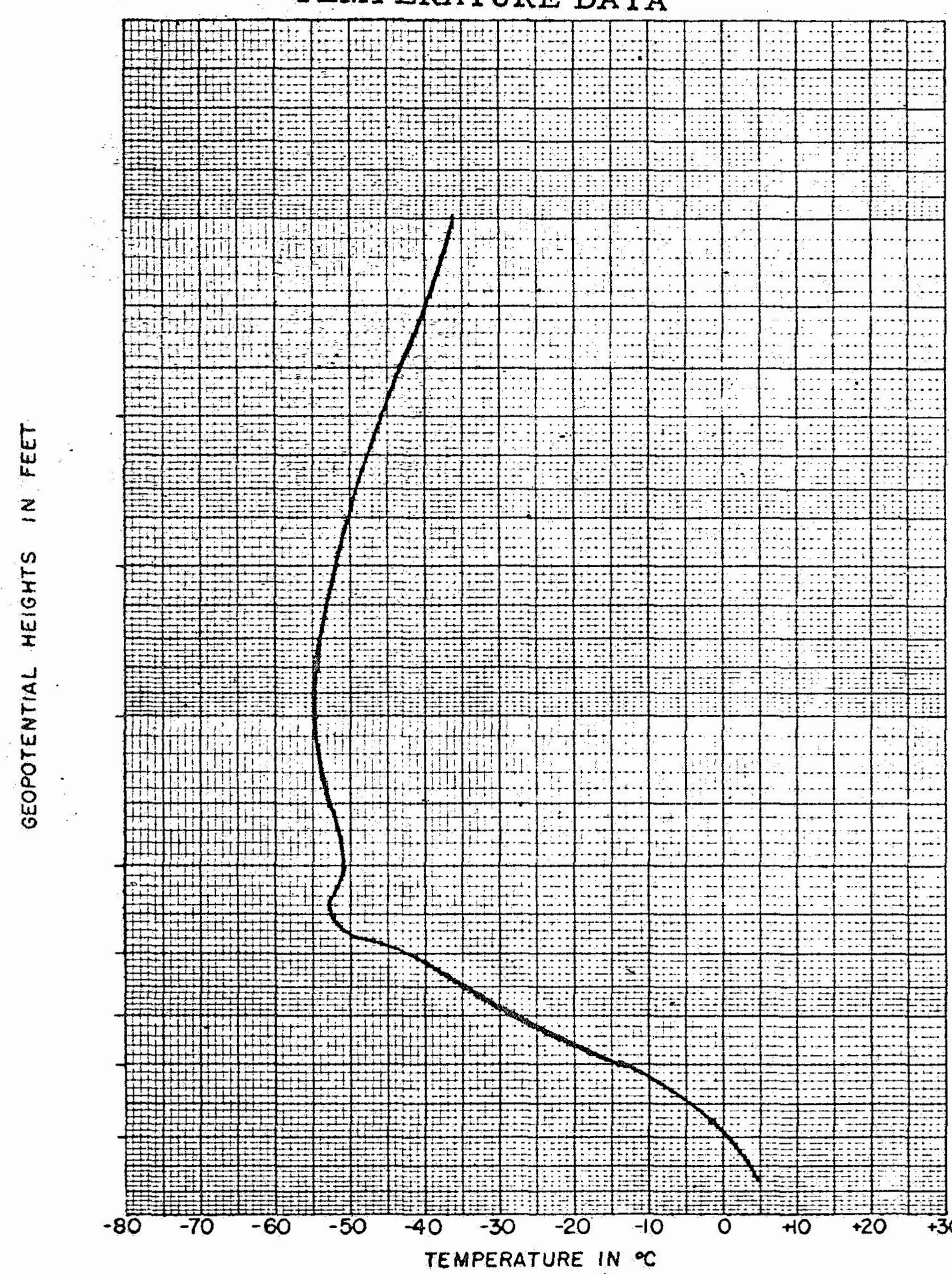
0293 LD

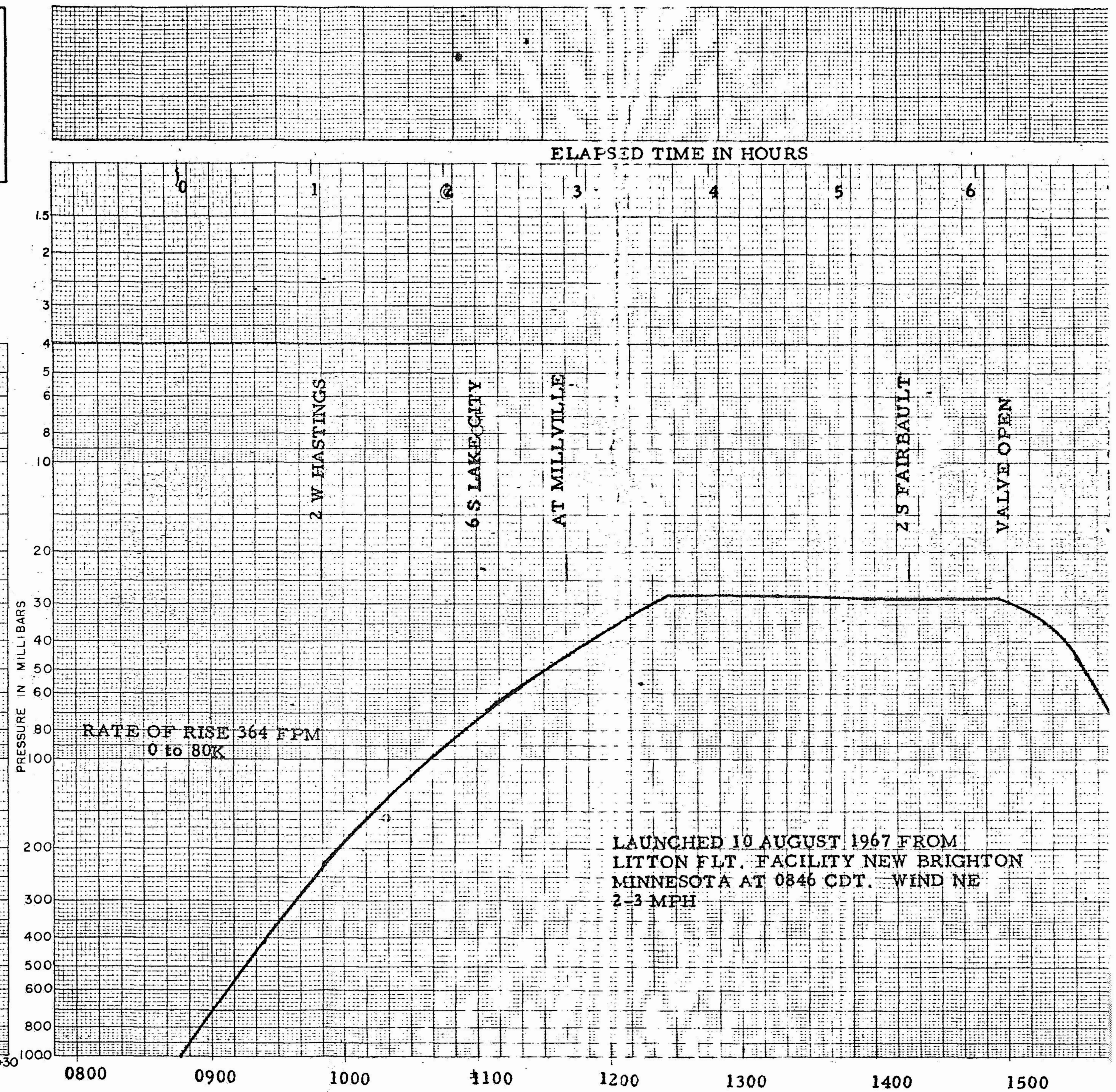
FLIGHT NO. 3045 DATE 10 August 1967
FOR JPL 59651
LOAD ON BALLOON 238 lbs
FREE LIFT 35 LBS= 8 %

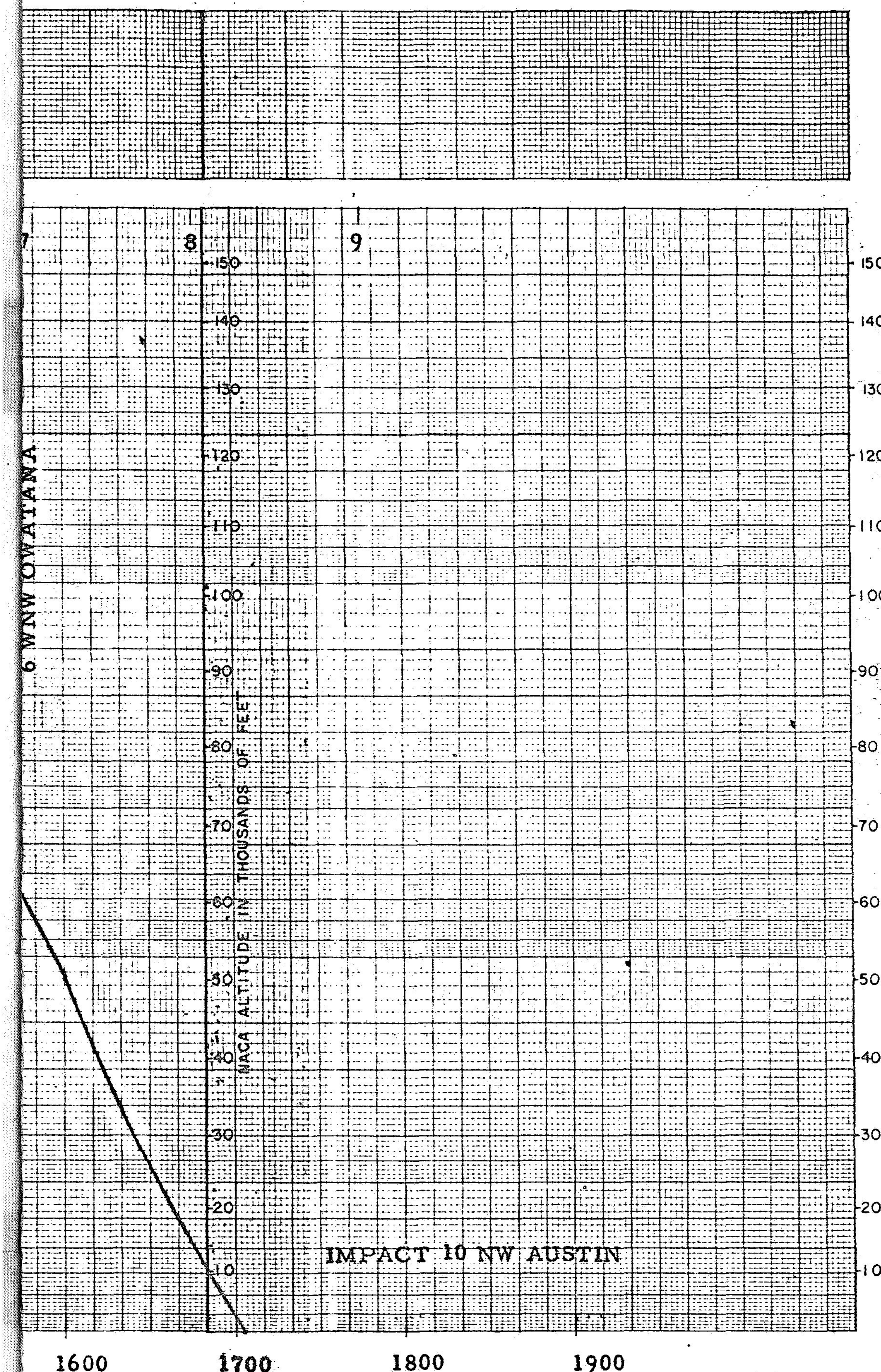
BALLOON TYPE	NUMBER	MATERIAL	WEIGHT
77-1-2	3	DRS 816 1.5 Mil	200 LBS.

ALTITUDE DATA

TEMPERATURE DATA







7
8
9
6 WNW OWATANA
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
NACA ALTITUDE IN THOUSANDS OF FEET
NACA ALTITUDE IN THOUSANDS OF FEET
IMPACT 10 NW AUSTIN
1600
1700
1800
1900

A-14

92