30

AFMDC-TR-59-24
ASTIA Document No. AD 215867

AFMDC-TR-59-24
ASTIA Document No. AD 215867

AIR FORCE MISSILE DEVELOPMENT CENTER

TECHNICAL REPORT

MANHIGH I

by

WINZEN RESEARCH, INC.

HOLLOMAN AIR FORCE BASE
NEW MEXICO

June 1959

AFMDC-TR-59-24
ASTIA Document No. AD 215867

AFMDC-TR-59-24
ASTIA Document No. AD 215867

MANHIGH I

flown by

J. W. Kittinger
Captain, USAF

as reported by

Winzen Research, Inc.

Aeromedical Field Laboratory

Directorate of Advanced Technology

AIR FORCE MISSILE DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
Holloman Air Force Base, New Mexico

June 1959

ABSTRACT

Operation MANHIGH I was the first of a series of manned balloon probes into the upper atmosphere, as a preliminary investigation to the Man in Space program. The structure and instrumentation of the capsule and aerostat are described, and the collected data are plotted and analyzed.

PUBLICATION REVIEW

This Technical Report has been reviewed and is hereby approved for publication.

FOR THE COMMANDER:

RUFUS R. HESSBERG
Lt Colonel, USAF (MC)
Chief, Aeromedical Field Laboratory

TABLE OF CONTENTS

MANHIGH I

I. OPERATION MANHIGH - FLIGHT I

At 2300 Central Daylight Time (CDT) on 1 June 1957, preparations were begun for the first manned stratosphere balloon flight on Project MANHIGH. This program, under the direction of the United States Air Force Aero-medical Field Laboratory, Holloman Air Force Base, New Mexico, was conducted by Winzen Research, Inc., Minneapolis, Minnesota.

The initial preparations for this flight were made at the Winzen Research plant where Captain J. W. Kittinger received his last preflight physical examination prior to donning his partial-pressure suit and the instrumentation for measuring his physiological reactions during the flight.

During the period of Captain Kittinger's preparation for his flight, the capsule, which would be his laboratory, was also being prepared for the flight. The liquid oxygen system was filled, and the chemicals were placed in the air regeneration unit. The electrical system and communications equipment were given a final operational check.

At 0030 CDT on 2 June 1957, Captain Kittinger entered the capsule, and again final checks were made to be certain that the equipment was operating properly. The capsule was sealed and then checked to make certain that it was pressure tight. The nitrogen content of the capsule was reduced by using a flushing procedure in which helium was used to replace the nitrogen in the capsule atmosphere. The purpose of this denitrogenation procedure was to reduce the possibility of bends in the event of an instantaneous decompression of the capsule at extremely high altitude.

Initial preparations were completed at 0330 CDT 2 June 1957 and the capsule was transferred by truck to Fleming Field at South St. Paul, Minnesota, arriving at Fleming Field at 0430 CDT. The flight preparations commenced immediately.

The pre-launch activities proceeded according to plan. The balloon was inflated and all flight equipment was installed. (See fig. 1).

At 0620 CDT all preparations were complete, the surface winds were peaking at approximately two knots, and synoptic meteorological conditions were ideal for the anticipated flight. At 0623 CDT the balloon was released from the restraining rollers of the launching platform, and as the balloon ascended slowly, the capsule was lifted into the air (fig. 2, 3, and 4).

Released by author, 6 February 1959.

FIGURE 1

FIGURE 2

FIGURE 3

FIGURE 4

At the time of launching, there were a number of tracking and photographic aircraft in the air. These included a USAF C-47 with Captain H. B. Fronkier as pilot, two USAF helicopters under the command of Captain L. B. McGrady, and a Navion chartered by Winzen Research.

Communications at the command post were maintained during the initial portion of the flight by means of a portable VHF transceiver. Approximately 20 minutes after launch Captain Kittinger advised that he was going to check the other channels on the VHF communications equipment. As he turned the channel selector knob on the transceiver, a mechanical failure of the selector resulted in his being unable to determine the frequency to which the transceiver was tuned; thus he was unable to transmit voice communications throughout the remainder of the flight. His only transmissions from this time on were accomplished by using the physiological and altitude telemetering HF transmitter as a CW code transmitter. The HF voice receiver was still operating properly, and he was able to read ground instructions. However, this became difficult during the later stages of ascent because of the proximity of a commercial broadcasting station that was transmitting on a wave length near Captain Kittinger's HF receiver wave length.

The breakdown in VHF communications necessitated a change in tracking procedures, since the CW transmissions from the capsule were being effectively received only at the Winzen Research plant. This information was relayed by telephone to the flight center at Fleming Field, with a resultant delay in obtaining critical information concerning the status of the flight operation.

Soon after launch it became apparent to Captain Kittinger that the capsule internal pressure was responding very slowly to the change in altitude. Inasmuch as the pressure response rate had never been experienced under actual flight conditions, it was necessary for Captain Kittinger to withhold any evaluation until it could be determined whether or not the capsule pressure would drop to the anticipated level. The loss of communications on the VHF transceiver resulted in a lengthy delay in reporting this problem. The first indication of impending trouble was received on the ground at 0807 CDT when Captain Kittinger reported that his liquid oxygen supply was down to two liters remaining. This was confirmed, and the command helicopter was called back to Fleming Field so that Lt. Col. D. G. Simons, Colonel J. P. Stapp, and O. C. Winzen could discuss the situation. It was necessary to obtain more information from Captain Kittinger before evaluation of the problem was possible. During this period, the balloon was floating at its ceiling altitude of 95,200 feet. The rapidity with which the oxygen supply was being depleted indicated that the fault was in the cabin pressure controller, and the decision to start a descent was made at 0854 CDT.

In an attempt to establish more direct contact with the capsule, the ground control function was transferred to the C-47 aircraft. At approximately 1000 CDT, Captain Kittinger was advised to switch his oxygen supply to the pressure suit in order to conserve the remaining oxygen. This procedure definitely established that the cabin pressure controller was responsible for the excessive loss of oxygen; therefore, by closing the vent valve from this unit, it was possible for Captain Kittinger to resume the normal capsule atmosphere breathing procedure - manually replenishing the oxygen through the constant flow valve as required.

The cloud cover had by this time obscured the balloon from view of the C-47, and the command function was transferred back to the Winzen communication post at the company plant. The C-47 remained on the ground until 1130 CDT, at which time Captain Kittinger had descended to 53,000 feet. At 1215 CDT, Captain Kittinger reported that he had descended through the tropopause. Further attempts to re-establish VHF communications were unsuccessful, and shortly after 1230 CDT, the balloon was sighted below the clouds. It was traveling in an ESE direction from a point directly south of Belle Plaine, Minnesota (see fig. 5).

The descent rate of the balloon was retarded by dropping part of the external batteries on individual parachutes (indicated by arrows in figure 5). Despite high surface winds and the heavily wooded nature of the terrain, the landing made by Captain Kittinger was executed with commendable control. The capsule passed over the tree tops and settled into a small clearing, landing at 1255 CDT on the bank of Indian Creek just north of Weaver, Minnesota (fig. 6). At the instant of contact, the balloon was released, and the capsule toppled into the shallow water of the creek. Immediately after the landing, the two helicopters landed in the clearing and assisted Captain Kittinger from the capsule. This was the conclusion of the flight which carried Captain Joseph Kittinger to the highest sustained altitude achieved by man until that time (see figure 7).

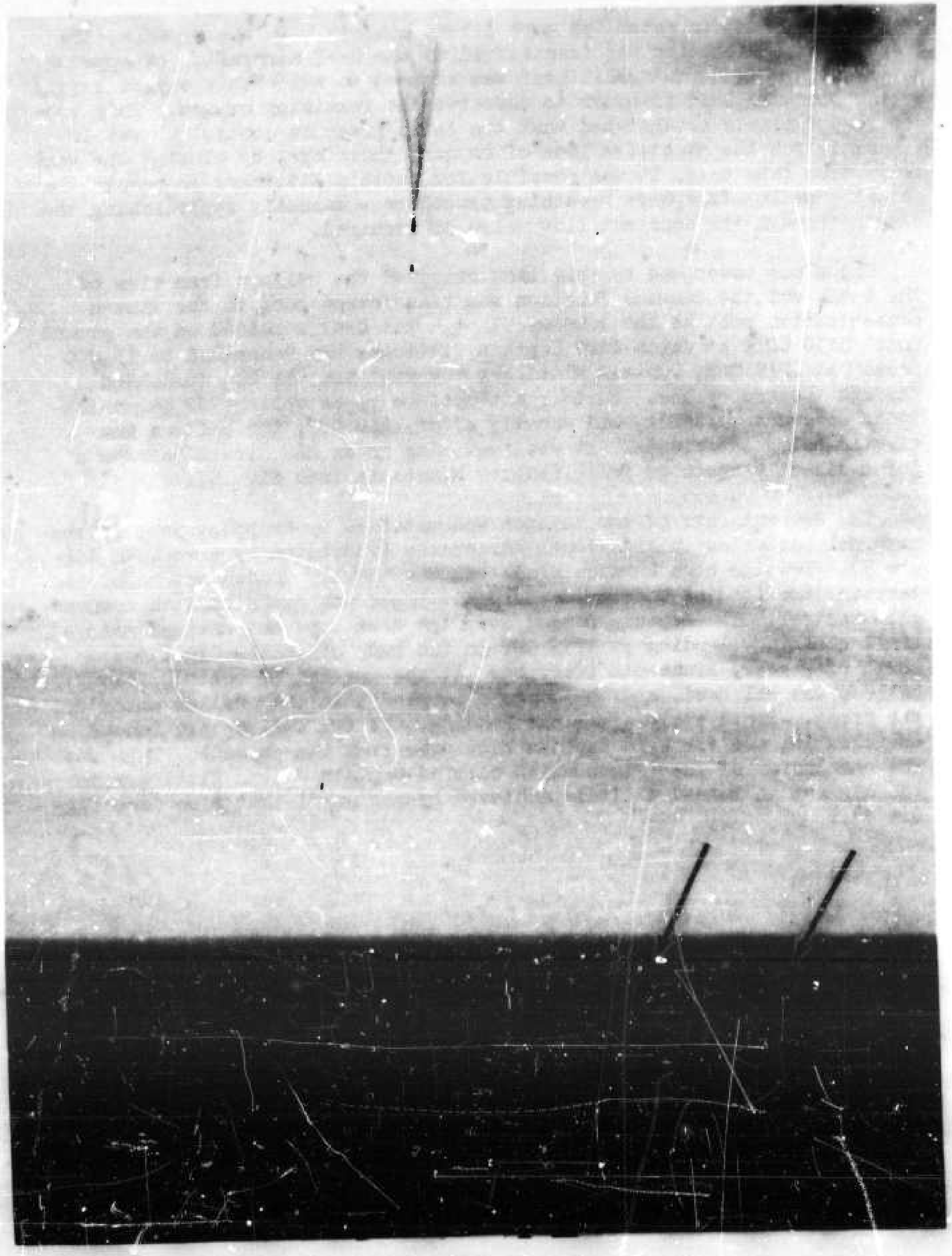


FIGURE 5

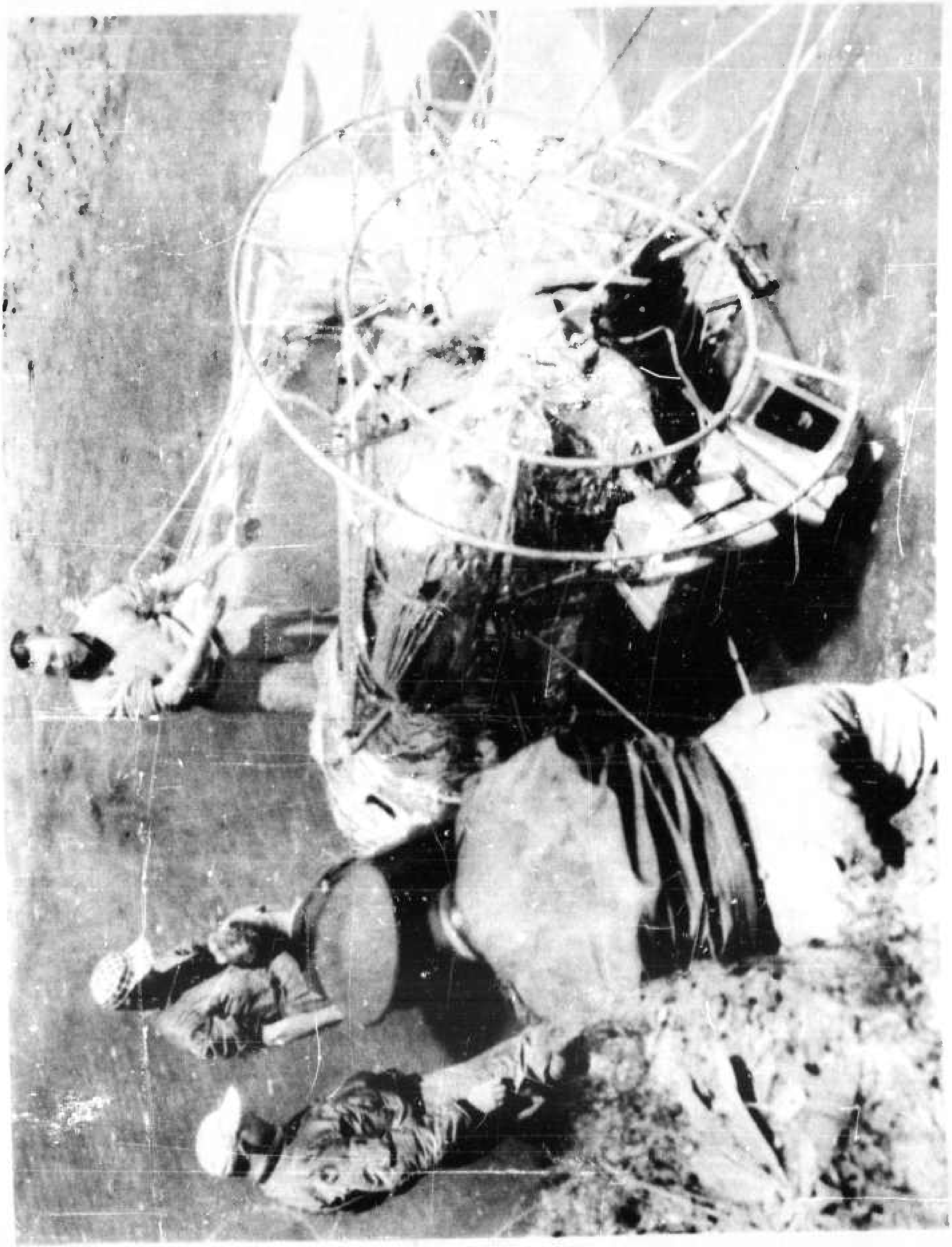


FIGURE 6

FIGURE 7

II. SYSTEM DESCRIPTION AND FLIGHT PERFORMANCE

A. General

The capsule used for the MANHIGH I flight was an aluminum-alloy, hermetically-sealed unit 8 feet high and 3 feet in diameter, having ends hemispherical in shape. (See fig. 8.) The capsule was supported in an upright position by a tubular aluminum structure to which various expendable equipment was attached. This structure was especially designed to serve as a shock-absorbing system during landing operations. The capsule shell was constructed of three separate sections which were hermetically sealed together by two circumferential clamps. The primary structural member of the system was the aluminum alloy casting which formed the center section of the capsule shell. This turret casting, in which the six portholes were incorporated, was the load-carrying member for almost all of the internal structure and equipment. The capsule was attached to an open 40.4-foot extended skirt-type parachute by means of six suspension fittings which were positioned circumferentially around the turret casting. The parachute was, in turn, attached to the balloon by a stabilizing suspension system to retard any capsule oscillations during the flight (fig. 9).

A pressure equivalent to that of 26,000 feet was selected as the control pressure in the capsule.

Oxygen for the pilot's breathing and for cabin pressurization was provided by a five-liter liquid oxygen converter and a 205 cubic inch high-pressure bottle. An emergency 90 cubic inch bailout supply was installed in the personal parachute harness worn by Captain Kittinger.

The sealed atmosphere in the capsule was chemically treated to remove carbon dioxide and moisture, and an external water evaporation-type cooling system was used to maintain the capsule temperature at a comfortable level (fig. 10)

The electrical and communications equipment was primarily installed internally, the main exception being the lead acid battery power supply which was mounted on the lower undercarriage ring. These batteries were equipped with individual parachutes and were to be used as ballast when expended.

Continuous recording of the flight progress and other essential information was provided by sequence cameras. These cameras provided photographs of the instrument panel and photographs of the earth during the flight.

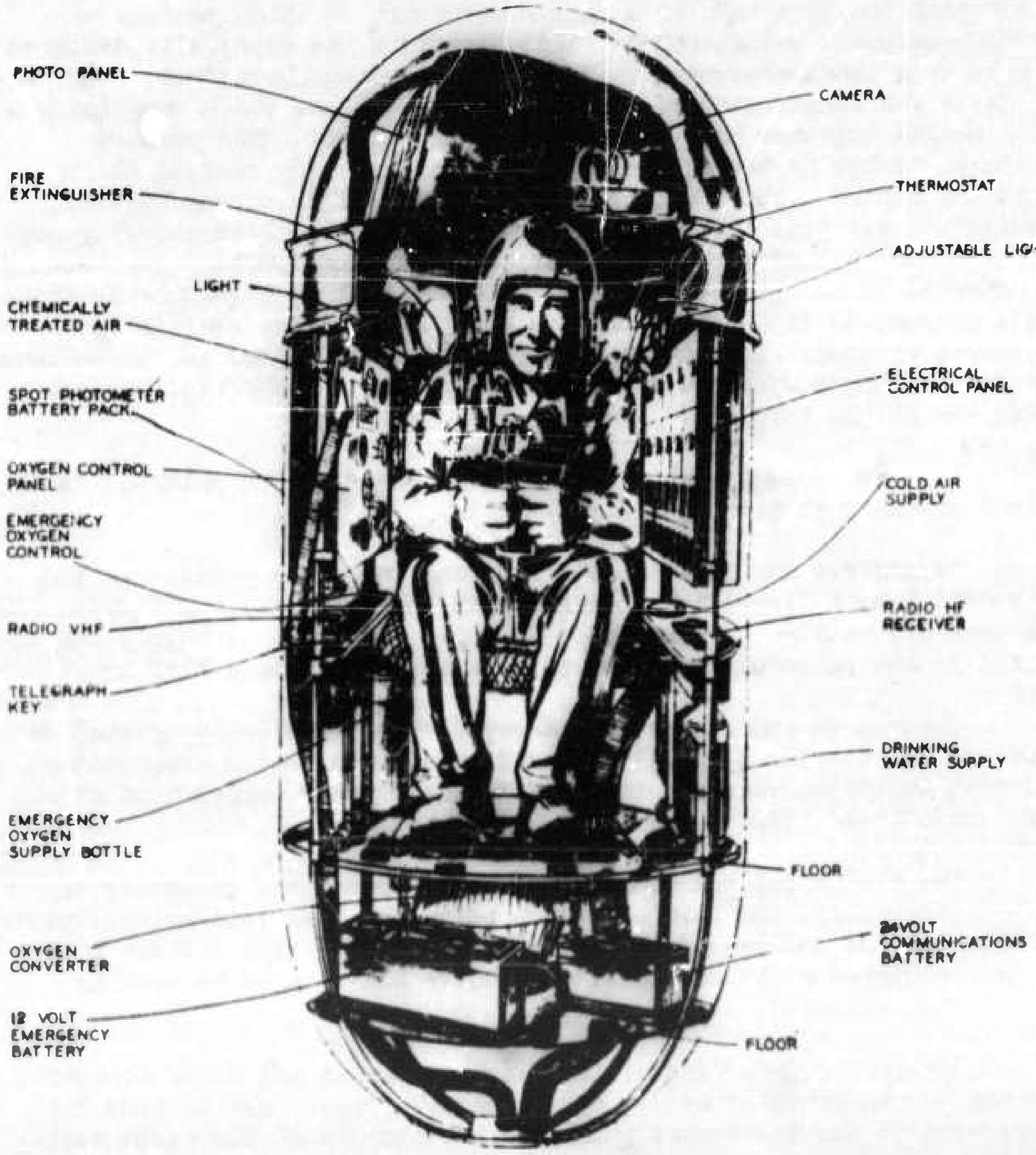


PHOTO PANEL
CAMERA
FIRE EXTINGUISHER
THERMOSTAT
ADJUSTABLE LIGHT
LIGHT
CHEMICALLY TREATED AIR
ELECTRICAL CONTROL PANEL
SPOT PHOTOMETER BATTERY PACK
OXYGEN CONTROL PANEL
COLD AIR SUPPLY
EMERGENCY OXYGEN CONTROL
RADIO VHF
RADIO HF RECEIVER
TELEGRAPH KEY
DRINKING WATER SUPPLY
EMERGENCY OXYGEN SUPPLY BOTTLE
FLOOR
OXYGEN CONVERTER
24 VOLT COMMUNICATIONS BATTERY
12 VOLT EMERGENCY BATTERY
FLOOR

FIGURE 8

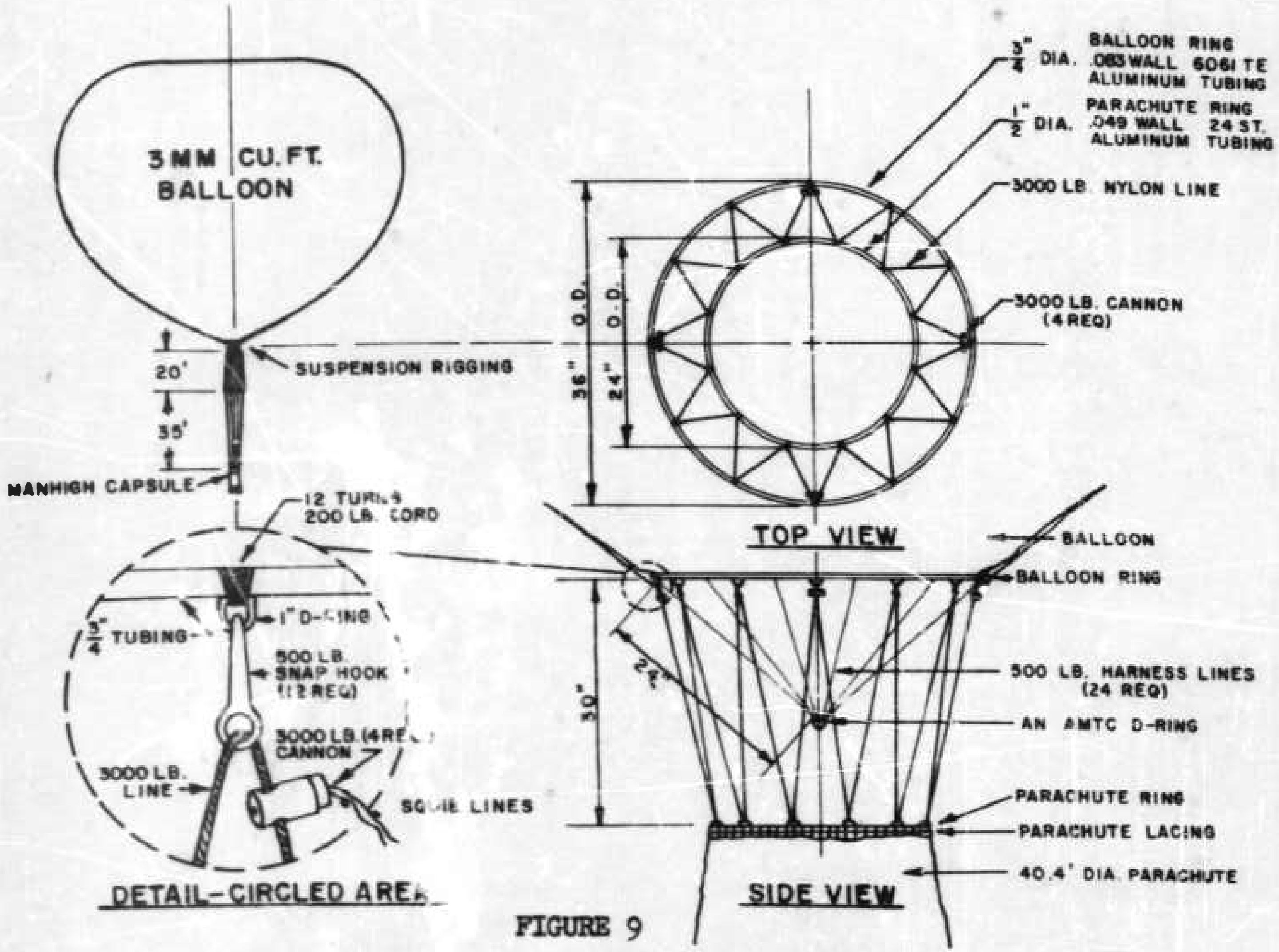


FIGURE 9

MANHIGH LOAD SUSPENSION

FIGURE 10

Various other items of equipment were installed for the purpose of performing a limited number of experiments and providing scientific data from the flight.

The balloon used for this flight had an inflated volume of two million cubic feet and was fabricated from polyethylene film. An electrical fail-safe valve was installed at the apex.

The telemetering equipment was to provide altitude information, as well as physiological information, concerning the reactions of Captain Kittinger throughout the flight. (See fig. 11.)

B. <u>Aerostat and Flight Controls</u>

The balloon used for Captain Kittinger's altitude record-breaking flight on 2 June 1957 was manufactured by Winzen Research, Inc. It was fabricated from polyethylene film two mils in thickness. The inflated volume of this aerostat was two million cubic feet and was of the Winzen Research natural shape FIST design. This design incorporated 60 gores with 120 integral heat-sealed load bands. Each load band had a rated tensile strength of 500 pounds.

Installed at the apex of the balloon was an electrically driven 14-inch diameter fail-safe gas valve. (See fig. 12.) This valve was controlled from the electrical panel inside the capsule. The actuation of this valve permitted Captain Kittinger to release the helium gas from the balloon in order to decrease the rate of ascent, initiate descent, or to increase the rate of descent.

Ballast for slowing the rate of descent or for initiation of or increase in rate of ascent was provided by the utilization of expended lead acid batteries mounted on the tubular undercarriage. In addition to the battery ballast, fine control was possible through the dropping of steel shot through a metering valve mounted below the ballast container. A total of 246 pounds of ballast was provided for Captain Kittinger's daylight flight.

The performance of the aerostat and flight controls was normal throughout the flight period.

C. <u>Oxygen and Capsule Pressurization</u>

During normal flight operations, the capsule pressure regulation and the breathing oxygen supply were controlled simultaneously by a single cabin altitude selection regulator. This regulator was designed to maintain automatically the capsule pressure equivalent to any preselected altitude between 12,000 and 40,000 feet (485 - 140 mm Hg). The normal altitude selection was 26,000 feet. This control pressure was manually

LAUNCH WEIGHT OF AEROSTAT

Weight Breakdown

Balloon		
Balloon with valve and all accessories	953	
Parachute	45	
Radio control and termination (balloon release)	14	
		1,012 lbs
Capsule		
Shell, 3 piece, including turret and landing gear	150	
Outboard air-conditioning and air re-generation, with water & chemicals	141	
Oxygen system with liquid O_2	62	
Photo panel, recording camera, strobe light	50	
Control panels and wiring	45	
Internal batteries (silver cells)	40	
Internal structure	30	
Communications gear (VHF, HF, Omni)	60	
Altitude recording and telemetering	20	
		598
Ballast		
External batteries (droppable)	196	
Steel shot	50	
		246
Pilot		
Pilot	160	
Personal equipment	65	
Food and water	15	
		240
Experiments		
Equipment for experiments	50	
Cameras plus film	20	
		70
TOTAL LAUNCH WEIGHT OF MANHIGH I AEROSTAT		2,166 lbs

FIGURE 11

FIGURE 12

adjustable by means of a calibrated adjustment knob on the oxygen control panel. Oxygen was to be metered into the capsule atmosphere from the 5-liter liquid oxygen converter at any time that the capsule pressure (because of pilot's oxygen consumption, carbon dioxide removal, and capsule leakage) fell below the preselected value. An emergency supply (205 cubic inches at 1800 psi) of oxygen was provided in the event the main supply should become depleted. A special bailout supply (90 cubic inches at 1800 psi) was integrated into Captain Kittinger's parachute harness.

In addition to the automatic capsule pressure regulator, a manually operated constant flow valve was provided for supplying oxygen to the capsule atmosphere in the event of failure of the automatic system.

Captain Kittinger wore a standard USAF MC-3 partial-pressure suit for protection in the event of a sudden decompression of the capsule or any contamination of the capsule atmosphere. Oxygen for breathing and suit pressurization was available from any one of the three sources. The liquid and emergency supplies could be routed to the suit by means of a selector valve located on the oxygen control panel.

The pressure suit operation was regulated by two automatic flow regulators located in the X-90 (bailout supply). When oxygen was supplied to these regulators from any one of the three sources, it was metered to the helmet on a pressure demand basis for the pilot's breathing. In the event that the ambient capsule pressure should drop below the equivalent of 43,000 feet altitude, oxygen would be supplied to the suit capstans to pressurize the suit.

A manual decompression valve was provided in order that any excessive pressure buildup in the capsule could be decreased by venting the excess to the atmosphere.

The failure of the oxygen and capsule pressurization system to function as anticipated resulted in the flight being shortened several hours from the planned flight duration of ten to twelve hours.

Within a few minutes after beginning his ascent, Captain Kittinger became aware that the capsule pressure was not dropping as fast as the atmospheric pressure. This resulted in a pressure differential increase which should not have occurred until after passing the altitude which corresponded to the cabin altitude selector setting. Inasmuch as the rate of pressure equalization during the initial stages of ascent had not been established under actual flight conditions, he decided to continue the flight with no deviation from normal procedure.

The breakdown in the voice communications system, which occurred also during this initial stage of ascent, resulted in an extended delay in reporting critical information to the command post, which was monitoring the flight on the ground.

Captain Kittinger's first real warning of the malfunctioning oxygen system was the rapidity with which the liquid oxygen supply was being depleted. Upon the instructions from the command post, Captain Kittinger initiated emergency oxygen and cabin pressure control procedures. This involved a shift to pressure suit operation to determine if the oxygen was being lost because of a large leak in the capsule itself. After it had been definitely established that the cabin pressure regulator was the cause of the malfunction, Captain Kittinger switched to manual pressure control. The descent had previously been initiated because of the critical loss in the oxygen supply. Captain Kittinger found it necessary to repressurize the capsule manually during descent. This was accomplished by opening one of the portholes in the capsule. It was never necessary to use the emergency oxygen supply, although the liquid supply was nearly depleted at the time of landing.

Postflight examination revealed that the pressure supply line and overboard vent line to the cabin pressure regulator had been crossed during installation. This resulted in the oxygen supply being dumped outside rather than inside the capsule.

Although numerous tests had been performed with the system on the ground, the operating characteristics of the regulator were such that the error was not discovered during these tests.

D. Air Regeneration and Temperature Control

1. Air Regeneration

Removal of carbon dioxide and water vapor from the capsule was accomplished by a chemical air-regeneration unit located external to the capsule. The chemicals used in the regeneration system were:

a. Anhydrous lithium chloride

b. Anhydrous lithium hydroxide

c. Anhydrous magnesium perchlorate

The chemicals were arranged and the airflow was such that the air passed over the lithium chloride first, then the lithium hydroxide, and finally the magnesium perchlorate. The lithium chloride served to remove moisture before the carbon dioxide was removed by the lithium hydroxide. The magnesium perchlorate removed moisture formed by the reaction between the carbon dioxide and lithium hydroxide, and moisture not removed by the lithium chloride.

The chemical air-regenerative system consisted of thirty cylindrical nylon bags eighteen inches long and two inches in diameter, containing the required absorptive chemicals, placed in a twelve-inch diameter vertical cylinder, so the axes of the bags were parallel to the axis of the cylinder. The capsule atmosphere was drawn from the bottom of the capsule at the rate of approximately 25 cfm, passed by the chemicals, and returned to the upper part of the capsule. Three different chemicals were placed into each bag in the following order:

Chemical	Position	Purpose	Per Bag	Total
Lithium chloride	Bottom	Predrier	150g	4500g
Lithium hydroxide	Center	Remove CO_2	125g	3750g
Magnesium perchlorate	Top	After drier	150g	4500g
Weight of bags			10.1g	304g
TOTAL			435.1g	13054g

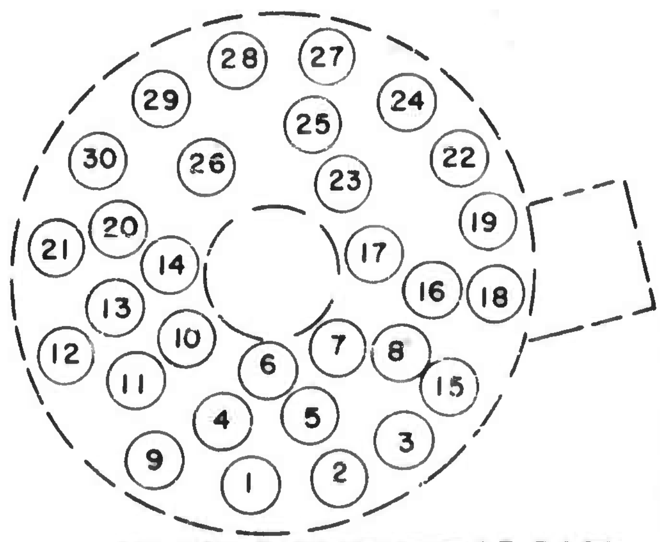
The final weights of chemicals, chemical solutions, and condensed moisture collected is tabulated in figure 13. A postflight chemical analysis of the lithium hydroxide was made at Holloman Air Force Base, showing that a sample taken at the periphery of the chemical bag had reacted with carbon dioxide to 19 percent of its capacity.

Postflight chemical analysis of the lithium hydroxide showed a 13 percent depletion of its capacity, indicating that the total weight increase of the lithium hydroxide was approximately 265 grams. This is equivalent to the moisture liberated by the reaction of approximately 448 grams carbon dioxide with lithium hydroxide. The subject was sealed in the capsule and the chemical system used for eleven hours and twenty-six minutes. Therefore, the average carbon dioxide removal rate was approximately 39 grams per hour or 0.0865 pounds per hour.

Assuming 264.5 grams weight gain in the chemical system attributed to the carbon dioxide removal reaction, the balance (759.4g) of the total weight gain (1023.9g) must be attributed largely to moisture conversion. The average rate of collection was 66.5g per hour or .1465 pounds per hour.

BAG NO.	WT. GRAMS
1	457.5
2	4505
3	459.4
4	449.9
5	450.0
6	454.2
7	456.3
8	463.9
9	458.5
10	453.1
11	453.0
12	456.9
13	469.8
14	461.6
15	461.6
16	451.8
17	458.6
18	461.9
19	464.1
20	457.2
21	458.5
22	456.7
23	462.0
24	464.5
25	456.5
26	460.6
27	460.0
28	462.6
29	461.6
30	483.9

GROSS 13776.7 GRAMS FINAL CHEMICAL WEIGHT
TARE 13054.0 GRAMS INITIAL CHEMICAL WEIGHT
NET 722.7 GRAMS CHEMICAL WEIGHT GAIN



RELATIVE POSITIONS OF BAGS IN CHEMICAL TANK

GROSS 108.2 WATER IN BOTTOM OF CHEMICAL TANK
TARE 77.0
NET 31.2 WATER WEIGHT GAIN IN CHEMICAL TANK
722.7 CHEMICAL WEIGHT GAIN
753.9 TOTAL WEIGHT GAIN IN CHEMICAL TANK
270.0 WATER COOLER CONDENSATE (EST.)
1023.9 GRAMS-TOTAL WEIGHT GAIN

FIGURE 13

2. Temperature Control

The capsule cooling was accomplished by circulating the capsule air through a finned-tube water-core heat exchanger. The heat exchanger was located externally and designed to remove approximately 1600 BTU/hr in the normal temperature range. No provisions were made for heating the capsule because the heat input from the pilot, air regeneration system, electrical components, and solar radiation would more than compensate for the heat loss from the capsule.

The air was circulated, by a 200 cfm axial-type blower, from the base of the capsule through the cooling core and returned to the upper section of the capsule. A water trap was located such that it collected condensation that formed on the cooling core.

The cooling system could be controlled either manually or automatically. If on automatic operation, a thermostat cycled the blower to maintain the selected temperature. A three-position selector switch with automatic, manual and off positions permitted the pilot to select and control the operation.

Since the water cooler did not operate effectively at high ambient pressures, a cap containing 80 pounds of dry ice was installed for supplementary cooling during prelaunch activities. This cooled the capsule to the 50°F range in the vicinity of the subject. It is estimated that approximately fifty pounds of dry ice remained in the cap at the time of launch 6-1/2 hours after the dry ice cap was installed, and because of this quantity of dry ice remaining, the capsule thermostat did not call for cooling at any time. The thermostat had been set at 70°F, but the highest ambient temperature noted during the preparation period was 62°F at 0215 CDT, and during the flight the highest observed temperature was 53°F.

E. Communications

The communications equipment provided for this flight included a VHF transceiver with an integral VOR receiver, an HF receiver for voice communications, and a telemetering transmitter which could be used for CW transmission in the event of failure of the voice communications.

As was indicated earlier in this report, because of a mechanical malfunction of the VHF transceiver, the CW transmitter had to be used for air-to-ground communication throughout much of the flight.

A system was used to telemeter the heartbeat and respiration of the subject by means of frequency shift keying of the beacon transmitter so that an audible signal was received for the respiration, and an overriding tone indicated the heartbeat.

The following frequencies were available in the gondola for communications and were assigned the reference code shown:

Frequency	Use	Code
118.5 mc	Voice special	A
122.8	Voice Unicom	B
122.1	Voice CAA Communication	C
121.5	Emergency	D
122.5	Tower	E
1724 kc	Aerostat transmitting only	F
3123 kc 6700.5 kc	Aerostat receiving only	G H

Channel F was used for telemetering or emergency CW communications, and to provide an ADF signal for tracking the balloon. An intervalometer was used to control this beacon transmitter so that the heartbeat and respiration of the subject was telemetered for four minutes out of each five, with one minute of altitude information. When used as a CW transmitter, it could not be used for telemetering functions.

Radio control cut-down could be effected on Channel H in case of emergency. The Air Force and Winzen Research tracking planes, as well as the transmitting station at the Winzen Research plant, were equipped to accomplish this cut-down.

F. <u>Instrumentation</u>

The flight recording instruments were mounted in a panel which was installed in the upper hemisphere. This panel was photographed at regular intervals by means of an intervalometer-actuated camera. The elapsed time between photographs was selective. A selector switch was provided on the electrical control panel to permit camera operation at either one-minute or five-minute intervals. (See fig. 14.)


USAF WINZEN RESEARCH INC. PROJECT
MAN HIGH
ABSOLUTE PRESSURE
CABIN PRESS
CLIMB
RATE OF CLIMB

FIGURE 14

The indications of the following instruments were recorded in this manner:

1. 0 - 80,000 foot altimeter
2. 62 - 200,000 foot altimeter
3. 0 - 2000 feet per minute rate of climb indicator
4. 8-day clock
5. Voltmeters
6. Cabin pressure
7. Cabin temperature
8. Outside air temperature

Mounted apart, but also in the upper hemisphere, was a magnetic compass to provide azimuth orientation.

The capsule atmosphere-indicating instruments provided for this flight included a Beckman Oxygen Analyzer, a Fyrite CO_2 Analyzer, oxygen pressure and quantity indicators, and a hand aspirated psychrometer.

Two Brinell tensiometers were installed in diametrically opposed parachute risers. These were intended to provide parachute opening shock data in the event that a parachute descent had been necessary.

The outside air temperature was measured by two white thermistors installed on a rotating rod such that one was moving at a higher velocity than the other. The resistances of these thermistors were then indicated on two 0 - 50 microampere meters on the photo panel. The ratio of the velocity of the two thermistors was such that the heat loss from one was twice the heat loss from the other. The actual air temperature was determined by the formula:

$$T_a = 2T_1 - T_2$$

where:

T_a = true air temperature

T_1 = temperature of the high velocity thermistor

T_2 = temperature of the low velocity thermistor.

An intervalometer, timed to the camera drive mechanism, shorted out the thermistors every twelfth exposure, thus providing a calibration point for the next eleven readings.

The time altitude curve shown in figure 15 was obtained from the photo panel data. The times and duration indicated for operation of the balloon apex valve were taken from the pilot's notes. This chart also records a comparison between the actual rate of climb and that indicated by the rate of climb indicator on the instrument panel.

The temperatures recorded by the individual thermistors on the thermistor waver will be found plotted in figure 16. This drawing also includes a curve showing the difference between the two readings. Figure 17 shows a comparison between the temperature sounding made during ascent with the thermistor waver and the temperature sounding made that same morning by the weather bureau station at St. Cloud, Minnesota. The descent temperatures are plotted in figure 18.

The computed altitude based on the temperatures plotted in figure 17 will be found in figure 19.

Data recorded by the pilot pertaining to the performance of the oxygen generation system will be found in figure 20. Tabulation of the final air regeneration data is shown in figure 13.

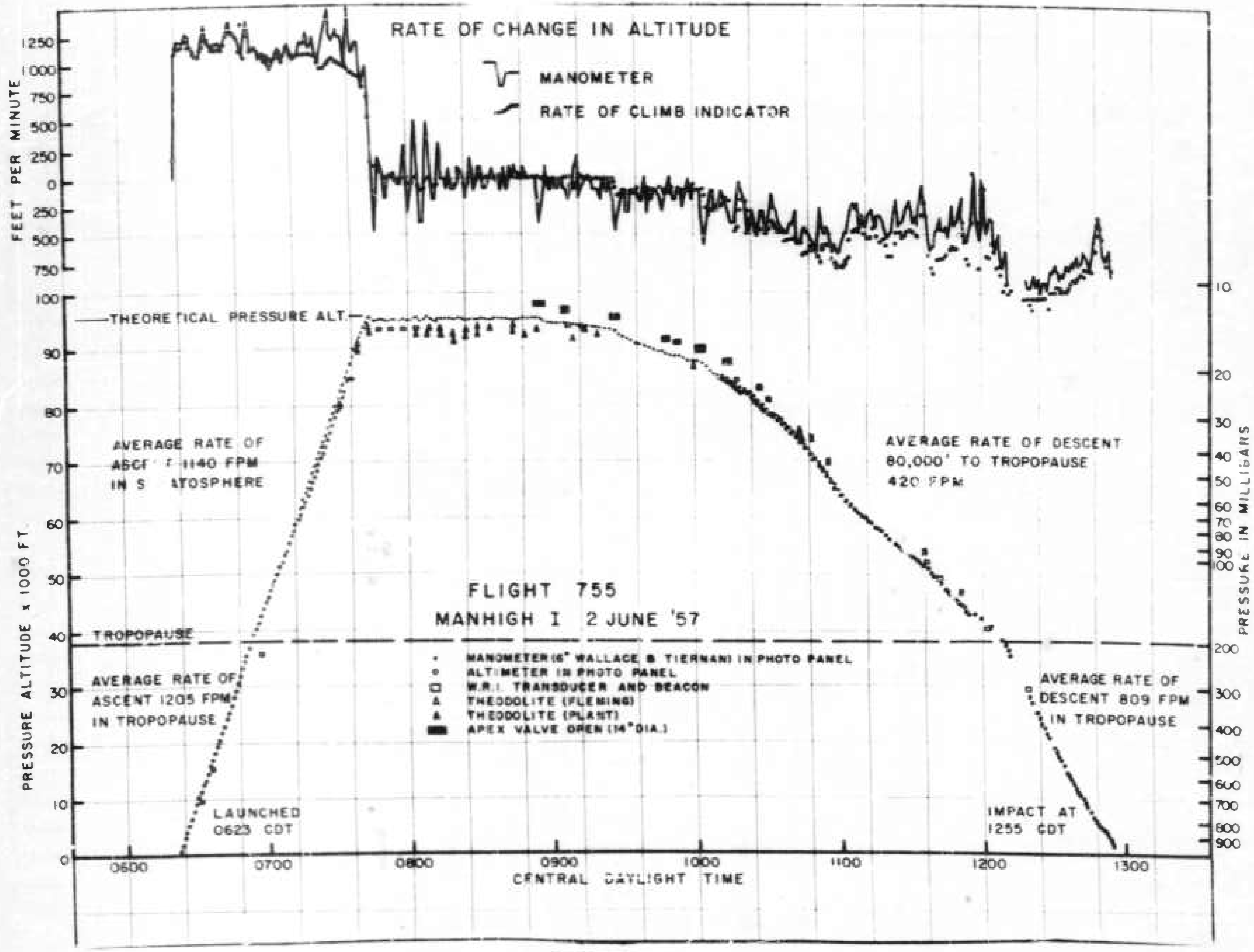

RATE OF CHANGE IN ALTITUDE
MANOMETER
RATE OF CLIMB INDICATOR
FEET PER MINUTE
THEORETICAL PRESSURE ALT.
AVERAGE RATE OF ASCENT 1140 FPM IN STRATOSPHERE
AVERAGE RATE OF DESCENT 80,000' TO TROPOPAUSE 420 FPM
FLIGHT 755
MANHIGH I 2 JUNE '57
TROPOPAUSE
AVERAGE RATE OF ASCENT 1205 FPM IN TROPOPAUSE
MANOMETER (6" WALLACE & TIERNAN) IN PHOTO PANEL
ALTIMETER IN PHOTO PANEL
W.R.I. TRANSDUCER AND BEACON
THEODOLITE (FLEMING)
THEODOLITE (PLAST)
APEX VALVE OPEN (14" DIA.)
AVERAGE RATE OF DESCENT 809 FPM IN TROPOPAUSE
LAUNCHED 0623 CDT
IMPACT AT 1255 CDT
PRESSURE ALTITUDE x 1000 FT.
PRESSURE IN MILLIBARS
CENTRAL DAYLIGHT TIME

FIGURE 15

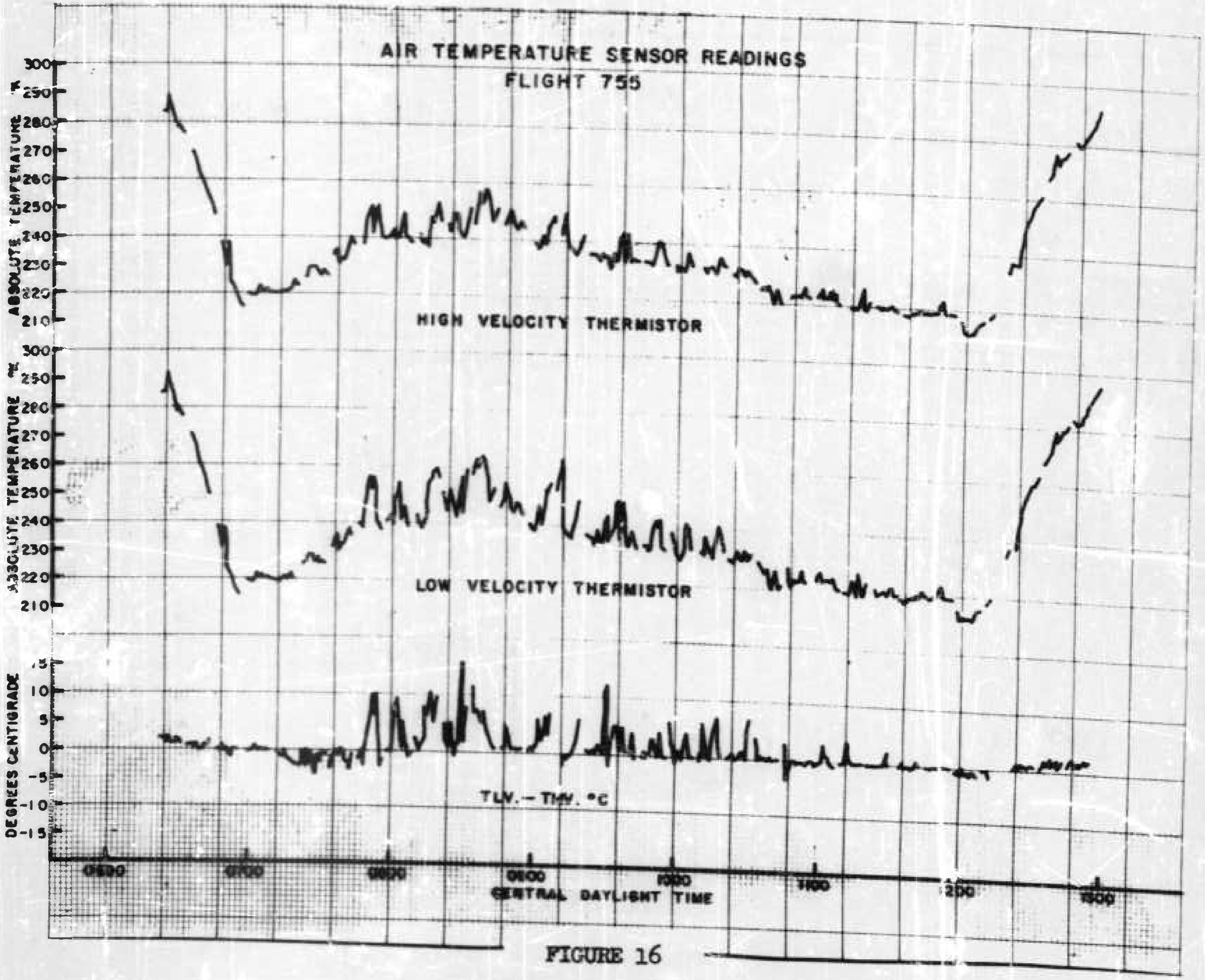

AIR TEMPERATURE SENSOR READINGS
FLIGHT 755
HIGH VELOCITY THERMISTOR
LOW VELOCITY THERMISTOR
TLV. – THV. °C
ABSOLUTE TEMPERATURE °K
DEGREES CENTIGRADE
CENTRAL DAYLIGHT TIME

FIGURE 16

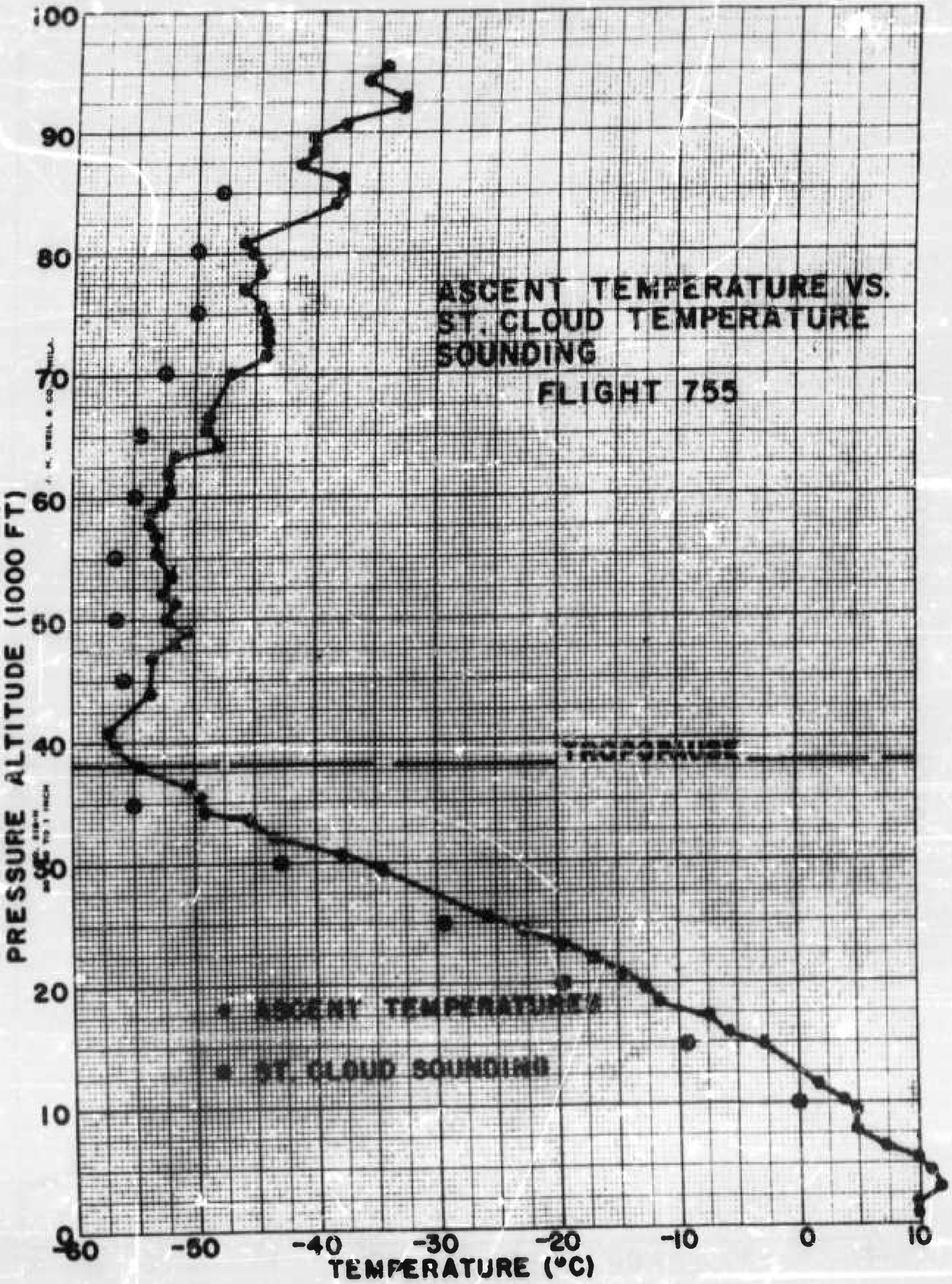
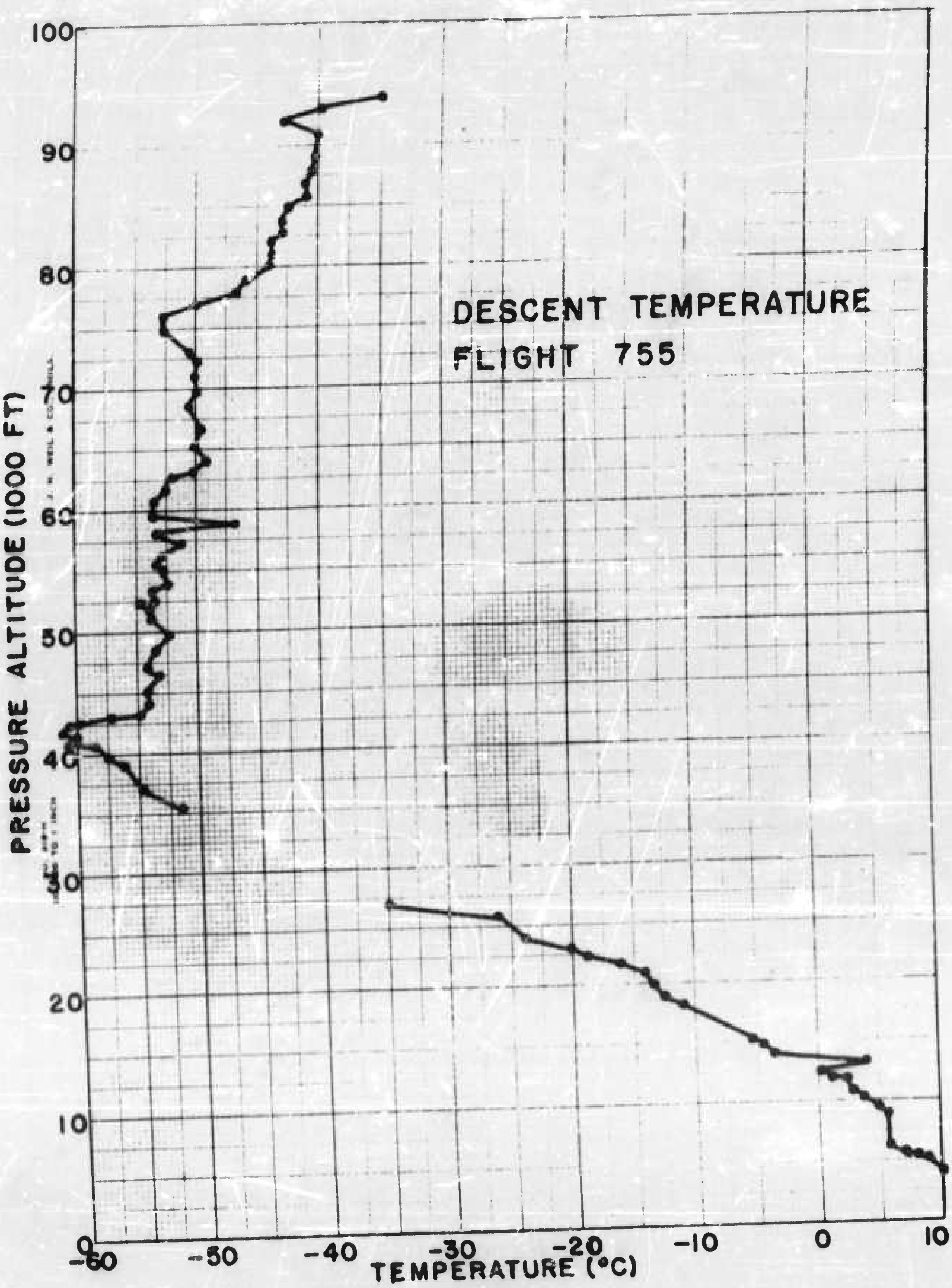

ASCENT TEMPERATURE VS.
ST. CLOUD TEMPERATURE
SOUNDING
FLIGHT 755
TROPOPAUSE
ASCENT TEMPERATURES
ST. CLOUD SOUNDING
PRESSURE ALTITUDE (1000 FT)
TEMPERATURE (°C)
100
90
80
70
60
50
40
30
20
10
0
-60
-50
-40
-30
-20
-10
0
10

FIGURE 17



DESCENT TEMPERATURE
FLIGHT 755
PRESSURE ALTITUDE (1000 FT)
TEMPERATURE (°C)
100
90
80
70
60
50
40
30
20
10
0
-60
-50
-40
-30
-20
-10
0
10

FIGURE 18

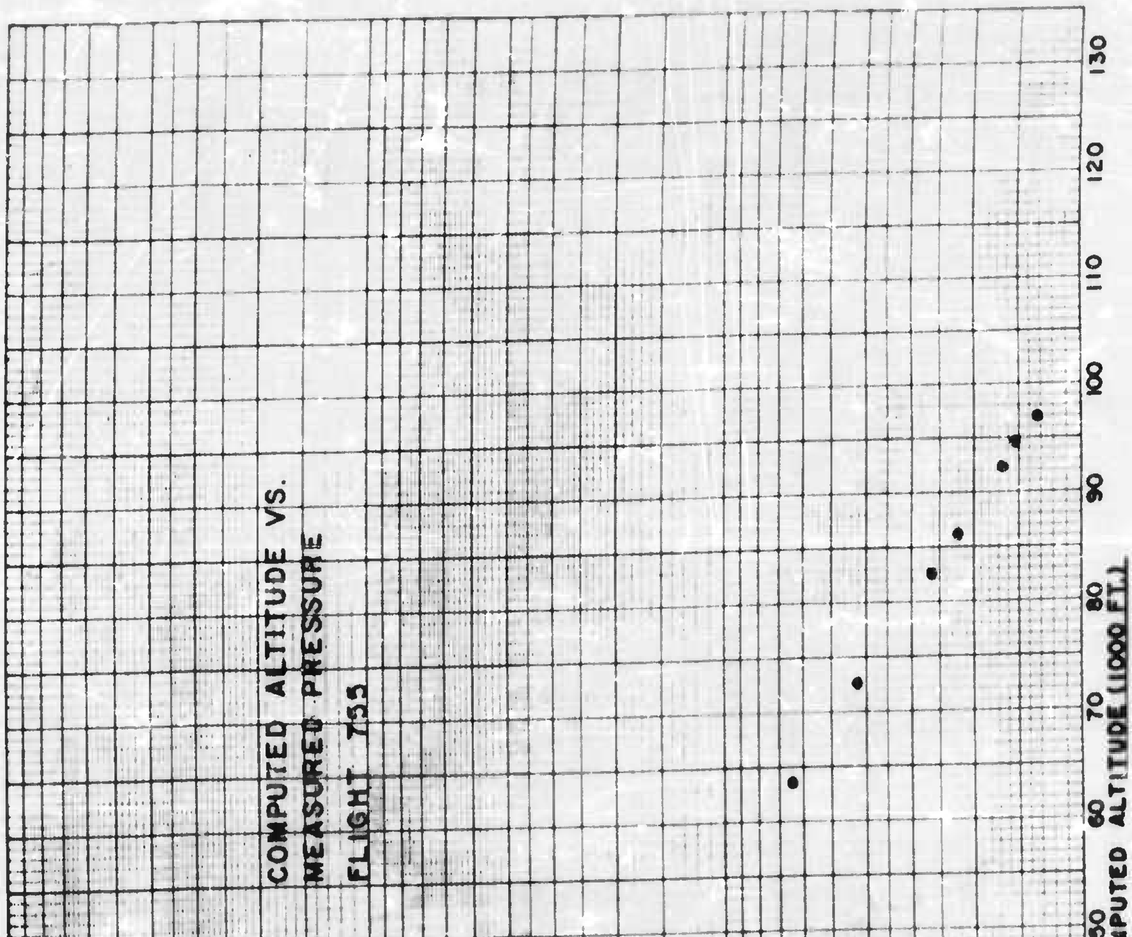

COMPUTED ALTITUDE VS.
MEASURED PRESSURE
FLIGHT 755
PRESSURE (MB)
1000
100
10
COMPUTED ALTITUDE (1000 FT.)
0
10
20
30
40
50
60
70
80
90
100
110
120
130

FIGURE 19

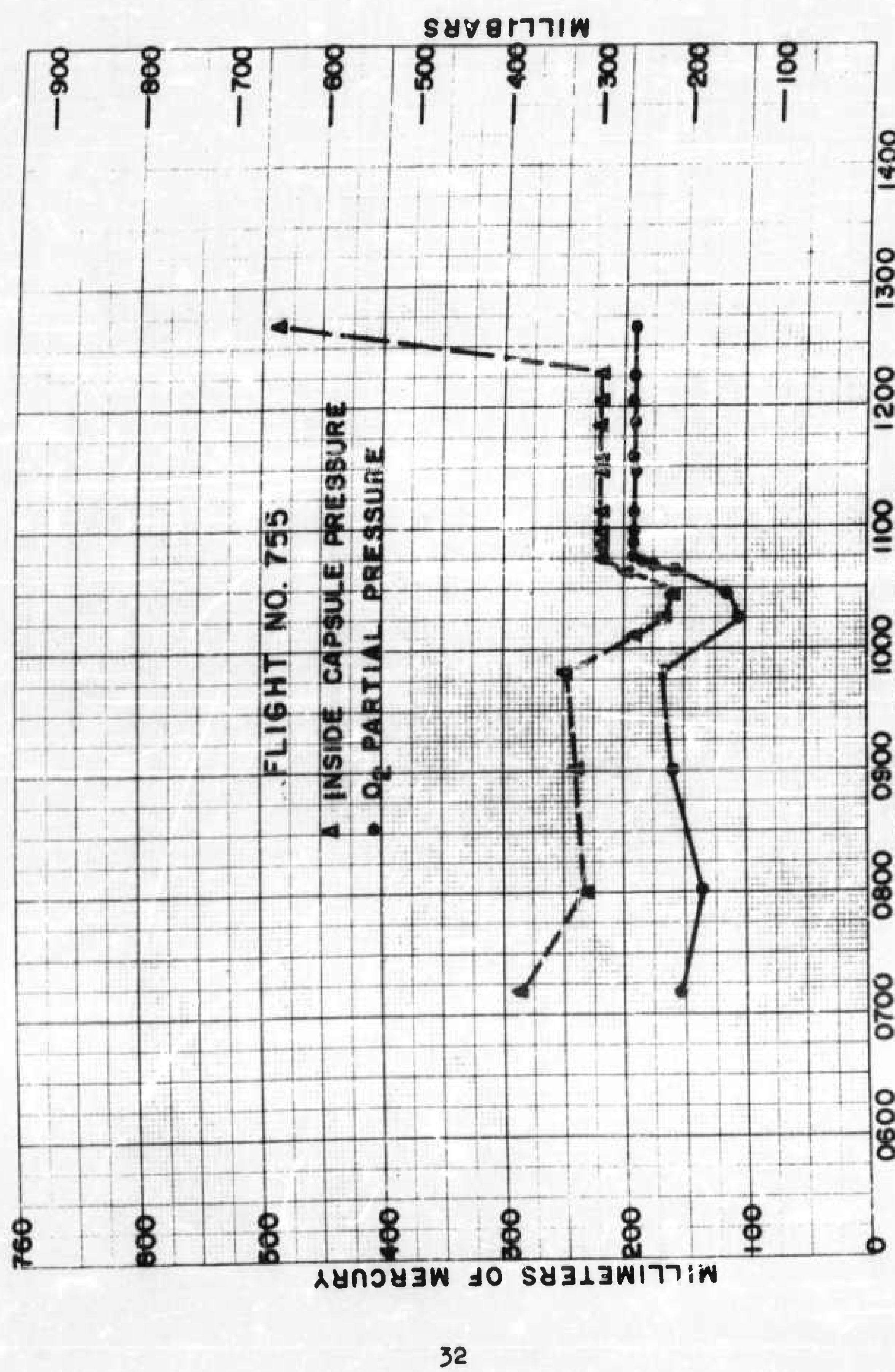

FLIGHT NO. 755
▲ INSIDE CAPSULE PRESSURE
● O2 PARTIAL PRESSURE
MILLIMETERS OF MERCURY
760
600
500
400
300
200
100
0
MILLIBARS
900
800
700
600
500
400
300
200
100
0600
0700
0800
0900
1000
1100
1200
1300
1400
CENTRAL DAYLIGHT TIME

FIGURE 20

III. FLIGHT ANALYSIS

The time altitude curve for Operation MANHIGH I is shown in figure 15. The instrument from which these data were taken was marked with the NACA pressure altitude scale. The theoretical altitude at which a balloon should float is calculated by using ICAO Standard Atmosphere tables. Since the pressure at which a balloon floats is directly proportional to the air temperature, and this temperature may differ from that used for computing the Standard Atmosphere table, it is possible for the actual balloon ceiling to fall short of or exceed the theoretical pressure ceiling. In this case, the maximum indicated pressure altitude which occurred at 0804 CDT was only 400 feet short of theoretical, a deviation of .32 percent. The geometric altitude for this pressure level can be calculated if the proper temperature soundings are made during the ascent. (See Section II, C, above.) The maximum indicated pressure altitude as recorded by the photo panel camera was 95,000 feet or 13.80 mb. It will be noted that this occurred approximately 20 minutes after the balloon reached ceiling - a period during which the balloon was undulating as it warmed and valved off the free lift gained from super-heating of the balloon gas. This undulation of the balloon is apparent up to ten minutes prior to descent.

It is interesting to note that in the early stages of the descent, valving gas started the balloon downward at a fair descent rate only to have it slow up shortly thereafter. This was due to the adiabatic warming of the balloon gas above air temperature during descent, causing negative free lift to be lost in thermodynamic drag. This can be seen from the temperature sounding for the descent in figure 18, which shows that the air actually became colder as the balloon descended, having the effect of restoring lift to the balloon. The air was nearly isothermal from 72,000 feet down to 63,000 feet where it again decreased in temperature, and it is noted that the balloon tended to level off at 62,000 feet.

The total valving time was 34 minutes, all of which occurred above the tropopause. Once the balloon had descended below the tropopause, the thermal lapse rate of the air temperature then aided the descent of the balloon.

In figure 15, the curve comparing the rate of climb as measured by the altitude gages to the indicated rate of climb of the rate of climb instrument in the photo panel, shows the indicator to be quite accurate up to an altitude of approximately 60,000 feet on the ascent, but not too reliable above an altitude of 10,000 feet on the descent.

The deviation of the theodolite altitude readings from that indicated by the Wallace and Tiernan Gage is the result of an error in bearing readings because of a lack of precise time measurements.

A. Temperature Sounding

As outlined previously in Section II, F, an attempt was made to arrive at the true air temperature by the use of two thermistors ventilated at different rates. This approach was used to overcome the difficulty of measuring temperatures in low density gases caused by poor thermal contact between the sensor and gas. The use of the differential between two thermistors reduces the effect of any variations in ventilation rates because of balloon movement. Figure 16 shows the data from this equipment. During ascent and descent the data appear quite reliable. However, when the balloon reached altitudes above approximately 62,000 feet, the thermistor temperatures fluctuated quite rapidly, both readings being in phase but not equal in amplitude, resulting in an erratic record. Assuming that the temperature was essentially constant would mean that there was a wide fluctuation in values for the ventilation factor. As will be recalled from figure 15, these measurements were not made in still air, for the balloon was in constant vertical motion even at ceiling.

Postflight analysis of these data has brought out several other conclusions concerning the equipment. The effect of the sun shining on the thermistors is not compensated for, and from Captain Kittinger's notes, it is probable that the waver was oriented toward the sun during most of the time at high altitude.

An error in the original calibration has been discovered because of a heating effect from the bridge used to measure the thermistor resistance. The remaining thermistors in the batch were recalibrated and found to yield a considerably different Beta factor, but since the thermistors used during the flight were destroyed during landing, they could not be recalibrated. A correction factor has been applied to the flight data, calculated from the other thermistors, but the data are not believed to be more accurate than ± 2°C. This may account for much of the difference between the soundings on this flight and that of the St. Cloud weather station. The sounding temperatures used were obtained from the high velocity thermistor, as it is believed to be the most nearly correct temperature.

It should be noted that the calibration error correction for the thermistors is considerably smaller at low temperatures, which accounts for the better agreement between high and low velocity thermistor indications at the lower temperatures during flight.

From the flight data, it can be seen that the real value of this method of determining temperatures of low pressure gases lies in the reliability which can be attached to a measurement when the two thermistor readings agree.

B. Computed Linear Altitude

In view of the unreliability of the temperature sounding, little importance can be attached to a computed linear altitude for this flight. However, using the soundings as shown in figure 17 and the tables published in Circular P of the United States Weather Bureau, a maximum linear altitude of 97,000 feet was computed. This is 1500 feet higher than the indicated NACA pressure altitude.

C. Conclusions

The following conclusions were formed as a result of this flight:

1. The flight operations procedures for this flight were adequate. Launching was accomplished without difficulty, and operations direction was able to cope with unusual and unforeseen developments.

2. Balloon behavior was as anticipated.

3. Flight controls were adequate. Command of the balloon was accomplished as desired.

4. The capsule proved in most respects capable of fulfilling its design requirements.

5. A human error in connecting the automatic oxygen control valve resulted in early termination of the flight.

6. The telemetering and communications system functioned as intended. However, a mechanical malfunction resulted in loss of voice communications from the aerostat early in the flight. The emergency provisions were capable of handling an extended flight.

7. The temperature measuring equipment did not function as intended. Analysis of the troubles indicated that the principles on which the instrument operates are valid, but improvement in detail is required. The temperature data gathered on the flight are not accurate enough to allow computation of a geometric altitude to within 750 feet or ±.8 percent.

8. On the basis of the temperature sounding of the weather bureau at St. Cloud, a maximum geometric altitude in excess of 95,500 feet can be assumed for this flight.

9. Other instrumentation and equipment operated in a satisfactory manner.

D. Recommendations

On the basis of the experience gained in this flight, these recommendations are made:

1. After repair to the oxygen system, a simulated flight test should be made in a stratosphere chamber to provide operational capability information prior to attempting a 24-hour flight.

2. The thermistors for the waver should be calibrated in the actual metering circuit in which they are used. They should be matched after calibration. Consideration should be made of a non-heating bridge circuit.

3. Accurate timing devices, such as WWV receivers, should be used at the theodolite stations.

4. The photo panel thermometer sensing element should be relocated to yield more valuable information.