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SIMULATED BALLOON FLIGHT TEST OF THE MODIFIED ULTRAVIOLET SPECTROMETER SYSTEM



**B. A. Burch
ARO, Inc.**

July 1967

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FOREWORD

The work reported herein was done at the request of the Air Force Cambridge Research Laboratory (AFCRL) (CRMP), Office of Aerospace Research, Air Force Systems Command (AFSC), under Program Element 62405394, Project 7621, Task 762102.

The results of tests presented were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), AFSC, Arnold Air Force Station, Tennessee, under Contract AF40(600)-1200. The tests were conducted from April 3 through 7, 1967, under ARO Project No. SR0723, and the manuscript was submitted for publication on June 12, 1967.

The major portion of the Balloon Spectrometer Equipment was designed and fabricated by Georgia Institute of Technology (GIT), Atlanta, Georgia, under Contract AF19(628)5707 with AFCRL.

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This technical report has been reviewed and is approved.

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ABSTRACT

A balloon-borne spectrometer package was tested under simulated flight conditions of temperature and pressure within an environmental chamber to evaluate the system operation. The system operated satisfactorily except for the pointing control and scan limit switch. These problems were generally related to low temperature effects, and the addition of a heater cleared up the pointing control problem.

CONTENTS

	<u>Page</u>
ABSTRACT	iii
I. INTRODUCTION	1
II. APPARATUS	1
III. PROCEDURE	5
IV. RESULTS AND DISCUSSION	5
V. CONCLUSIONS	7

TABLE

I. Spectrometer Package Instrumentation	4
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APPENDIX

Illustrations

Figure

1. Balloon Instrument Package	11
2. Balloon Flight Altitude	12
3. Balloon Flight Temperature	13
4. Aerospace Research Chamber (12V)	14
5. Schematic of N ₂ Inbleed	15
6. Test Schematic	16
7. Air Temperature Probe	17
8. Simulated Flight Test Altitude	18
9. Simulated Flight Test Temperature	19
10. Pointing Control Amplifier Temperature	20

SECTION I INTRODUCTION

An ultraviolet spectrophotopolarimeter was designed to measure the intensity and polarization of the natural sky background to an altitude of 120,000 ft.¹ During previous balloon flights and a simulated flight test, several components malfunctioned because of low temperature.² The spectrometer package was modified to overcome these problems. In order to evaluate the effectiveness of the modification, the spectrometer package was tested in the Aerospace Research Chamber (ARC) (12V), AEF at AEDC.

The complete spectrometer package was tested under simulated flight conditions of real-time variation of air temperature, pressure, and location of the sun. During the simulated ascent, malfunctions of flight hardware were experienced.

SECTION II APPARATUS

2.1 SPECTROMETER PACKAGE

The balloon-borne ultraviolet spectrophotopolarimeter package (Fig. 1, Appendix) consists of two principal elements (1) a sun pointer system which furnishes elevation and azimuthal stabilization with the sun as reference for the second unit and (2) a precision spectrometer. The coarse pointing control provides the azimuth adjustment to align the yoke and fine eye block with the sun. Then the fine pointing control, with elevation and azimuth motions, aligns the fine eye block parallel to the sun's rays, thus providing a stable reference for the spectrometer package.

The spectrometer is designed to measure the natural ultraviolet radiation of the sky from horizon through zenith and on to the opposite

¹Hodgdon, Ellis B. "Calibration and Data Reduction of an Ultraviolet Spectrophotopolarimeter." AFCRL-66-847, October 1966.

²Burch, B. A. "Simulated Balloon Flight Test of an Ultraviolet Spectrometer System." AEDC-TR-66-163 (AD489065), September 1966.

horizon. This scanning is accomplished by a programmed stepping of the spectrometer through a vertical arc which passes through the sun. Before reversing direction at the horizon, motion is stopped for spectrometer calibration. The reversing is initiated by a microswitch which actuates the electronic switching. The polarimeter includes a quarter-wave plate and drive mechanism which is used to measure the polarization of the incident radiation. All data from the spectrometer are conditioned and multiplexed by the Pulse Amplitude Modulated (PAM) commutator, then fed into the telemetry transmitter. This equipment is mounted within an open framework gondola, which also contains the auxiliary apparatus, e.g. batteries, telemetry package, and control circuits.

The spectrometer package had been modified from that previously tested by mounting the pointing control amplifiers in a pressure container and adding thermostatically controlled heaters. The quarter-wave plate mechanism, previously lubricated with grease, had a silicone oil on the bearings, and the gears were operated dry. Two backup systems were added to the spectrometer package - a watch and a wide-angle camera. The complete flight package was tested using an auxiliary power supply for the batteries and a direct connection of output data signals, omitting the telemetry transmitter.

The simulated balloon flight altitude and temperature profiles requested by the user are shown in Figs. 2 and 3. The pressure equivalent of the geometric altitude was determined from the U. S. Standard Atmosphere, 1962.³ The altitude tolerance was ± 2000 ft, as shown in Fig. 2. The air temperature tolerance was $\pm 10^\circ\text{F}$, as shown in Fig. 3.

2.2 AEROSPACE RESEARCH CHAMBER (12V)

The ARC (12V) (Fig. 4) is a stainless steel space simulation chamber having a working volume 10 ft in diameter and 12 ft in height, capable of attaining 10^{-9} torr pressure. The chamber has a liquid-nitrogen (LN_2)-cooled liner which provides a 77°K heat sink and a cryopump for water and carbon dioxide (CO_2). The walls of the chamber contain a shielded array of 20°K gaseous-helium (GHe)-cooled cryosurfaces, which will pump oxygen (O_2), nitrogen (N_2), and other 20°K condensable gases. The chamber mechanical and diffusion pumping system consists of a 750-cfm roughing pump, a 140-cfm forepump, a 750-cfm blower, and a 50,000-liter per second oil diffusion pump.

³U. S. Government Printing Office, Washington, D. C. U. S. Standard Atmosphere, 1962.

The chamber is equipped with an off-axis, top sun solar simulator irradiating a working volume 8 ft in diameter by 8 ft deep at one solar constant. A 16-channel system of tungsten filament lamps is available to provide the radiant energy to simulate albedo radiance or other varying heat loads.

Only the mechanical pumps were used to obtain the maximum altitude, 120,000 ft. A temperature-controlled gaseous nitrogen (GN_2) inbleed was used to help control both pressure and temperature during the simulated trajectory. Four tungsten filament lamps were used to control the temperature of the LN_2 liner as desired. During the test, the liner was not filled completely with LN_2 , but only enough LN_2 was admitted to lower the liner to the desired temperature. Thus the gas temperature and pressure in the chamber were controlled by combinations of inbleeding GN_2 , LN_2 cooling of the cryoliner, regulating power to the heat flux lamps, and using various mechanical pumps.

The gas inbleed system, schematically shown in Fig. 5, supplied N_2 at pressures of 0 to 150 psi, with flows of 0 to 40 standard cfm, and at temperatures of 70 to -70°F . The inbleed gas flow was manually regulated with a needle valve. The gas was cooled by passing it through an LN_2 heat exchanger. Dry N_2 was selected as the inbleed gas instead of atmospheric air, thus avoiding condensation on the surfaces of the heat exchanger, test article, and chamber liner, as well as preventing fog in the chamber. The gas was injected into the chamber through a multiorifice sphere, centered slightly above the test article, to ensure uniform circulation.

Two high intensity light sources were located in the chamber to serve as simulated suns or reference points. These were located 95 deg apart near the chamber walls, as shown in Fig. 6. Each light source was two 1000-watt Colortran® lamps, with one set orientated vertical and the other horizontal.

2.3 INSTRUMENTATION

The measurements made during the test consisted of the pressure and the air temperature in the chamber, temperature of various component parts, and the output from the spectrometer package. The data were transmitted from the ARC 12V by hard lines to the Universal Data System (UDS). The UDS was used to gather, display, and reduce test

data. Printed tables of both raw data as received from the spectrometer package and pressure and temperature data reduced by the system computer were obtained.

The data recorded consisted of two chamber pressures, six air temperatures, and 12 spectrometer package component temperatures. The location of the 12 thermocouples on the spectrometer package is given in Table I. The pressure transducers and air temperature probes were located as shown in Fig. 6. The pressure transducers, range from 0 to 1 and from 0 to 15 psia, were orientated toward the chamber center. Small wire copper-constantan thermocouples (Fig. 7) were used to provide a rapid response from the temperature probes. The long bare leads were to assure equilibrium with air temperature and to minimize conduction from the support.

TABLE I
SPECTROMETER PACKAGE INSTRUMENTATION

UDS Channel	Instrument	Description
1	Pressure Transducer	0 to 15 psia
2	Pressure Transducer	0 to 1 psia
3	Thermocouple	Pointing Control Amplifier
4		Pointing Control Container
5		Reference Battery
6		Quarter-Wave Plate Case
7		Quarter-Wave Plate Drive
10		Instrument Body
11		Gondola Frame
12		Water Support Bar
13		Wide-Angle Camera
14		Gun Camera
15		Battery Pack, Wide-Angle Camera
16		Solar Cell
17 - 24	Air Temperature Probes	
25	Photomultiplier 1	
26	Photomultiplier 2	
27	A-C Voltage	
30	Solar Cell Output	
1001 - 1035	PAM Signal	

The data output was taken from the commutator of the spectrometer package and consisted of six channels of analog data fed directly into

UDS and one PAM signal fed through the PAM synchronizer of UDS. Each data channel was scanned every 5 min during the test period.

Pressure and temperature data necessary for control of the chamber environment were available at the chamber by parallel readout of the air pressure inputs to UDS and direct readout of the air temperature from adjacent thermocouples.

SECTION III PROCEDURE

3.1 GAS TEMPERATURE AND PRESSURE CONTROL

Continuous monitoring with manual regulation of internal chamber pressure and gas temperature was used to maintain the desired flight conditions. Pressure simulation was achieved by varying the rate of gas inbleed and the pumping capacity. The pump capacity required was lowest initially and was increased by changing pumps or combinations of pumps as altitude increased. Gas inbleed was used throughout most of the test to prevent temperature stratification and uneven cooling within the chamber. Gas temperature was varied by cooling or warming both chamber liner and inbleed gas. The liner was cooled by periodically admitting small amounts of LN₂ and was warmed with the heat flux lamps.

3.2 TEST PROCEDURE

Power was applied to the telemetry equipment and motors of the test article, and the operation of the complete system was checked. The chamber was closed, and the desired pressure and temperature simulation was begun. Data were periodically recorded, and continual visual observation was maintained throughout the test run. A changing reference point was required to verify the performance of the pointing controls. This was accomplished by operating the two light sources alternately for 10-min periods.

SECTION IV RESULTS AND DISCUSSION

4.1 RESULTS

The purpose of this test was to determine if there were any undesirable pressure-temperature effects to the spectrometer flight package.

The simulated pressure and temperature are compared with the desired flight environment in Figs. 8 and 9. The gas temperature is an average value of the four thermocouples located around the flight package at 23-in. elevation. The simulated flight began at a simulated altitude of 4700 ft and 53°F with all systems operating normally. The simulated altitude and temperature were maintained within their tolerance except after 75 min of flight, when both the pumping system and pressure transducers were changed.

During the early part of flight there was some feedback to the pointing control while the spectrometer was in the calibration cycle. Some fluctuation was observed in the speed of action of the quarter-wave plate mechanism and the commutator motor. The commutator motor speed continued to vary during the test, requiring adjustment of the power input to correct for this variation. Commutator speed variations of greater than ± 10 percent were experienced, which caused loss of synchronization and the recorded data scan at that time. After 83 min of flight the pointing control failed to lock in elevation, at which time the amplifier temperature was 22°F, as shown in Fig. 10. After 96 min, the microswitch and reversing control circuit of the spectrometer did not operate. All the power to the spectrometer package was immediately turned off to prevent damage to the shaft, and the test was halted. After the test chamber had been returned to atmosphere, the spectrometer package was inspected, and it was observed that the backup watch failed after an hour of flight.

In an effort to define the cause of the difficulties encountered in the simulated flight test, an auxiliary heater was added to the pointing control amplifier case. The spectrometer package operation checked satisfactorily, and a second test was begun.

During the second simulated flight test, the temperature of the pointing control amplifier was monitored and the auxiliary heater manually adjusted to maintain the temperature between 60 and 70°F as shown in Fig. 10. The commutator motor speed varied during the second test and was regulated by adjusting the power input. After 82 min the quarter-wave plate mechanism slowed down. At 95 min of simulated flight the spectrometer indexed past the reversing microswitch, and the power was turned off to protect the equipment. During this test the pointing control had performed satisfactorily with the additional heat source.

4.2 DISCUSSION

4.2.1 Spectrometer Package

In the first simulated balloon flight, malfunctions occurred in the pointing control and the reversing control circuit. In previous flights and tests the pointing control had not functioned properly. However, this was the first observed malfunction of the reversing switch. The quarter-wave plate drive, a previous problem area, operated although it experienced some speed fluctuation after 60 min of flight. The auxiliary heater mounted on the pointing control amplifier case for the second trial eliminated the cause of the malfunction. The reversing control circuit failed again. Although no complete and detailed calculations have been made because of lack of detailed drawings, it appears that the cold temperature affects a capacitor in the reversing control circuit. This capacitor was located on an unheated area of the yoke where the temperature would be approximately 0°F at the time of failure. It appears that a small heater for the quarter-wave plate drive would be useful to eliminate the speed fluctuation.

The component temperature and spectrometer package output data should be helpful in conducting additional tests on the components which failed. Selection of parts which will withstand the lower temperature or supplying heat to critical components are two possibilities to be considered in eliminating the temperature problems.

4.2.2 Chamber Operation

The high altitude environmental chamber was successfully adapted with minor additions to simulate the real-time pressure temperature profile of the balloon flights.

SECTION V CONCLUSIONS

The spectrometer package experienced several malfunctions during the simulated flight conditions of balloon ascent. The pointing control modification of the thermostatically controlled heaters was insufficient since it failed during the first simulated flight. The addition of an auxiliary heater corrected this problem during the second test. The malfunction of the reversing switch and circuitry occurring during both flights was caused by low temperature. The quarter-wave plate drive, which had been modified because of previous failure, experienced some variation in operating speed. Using the results of this test, suitable changes or redesign can be accomplished to overcome the problems encountered.

**APPENDIX
ILLUSTRATIONS**

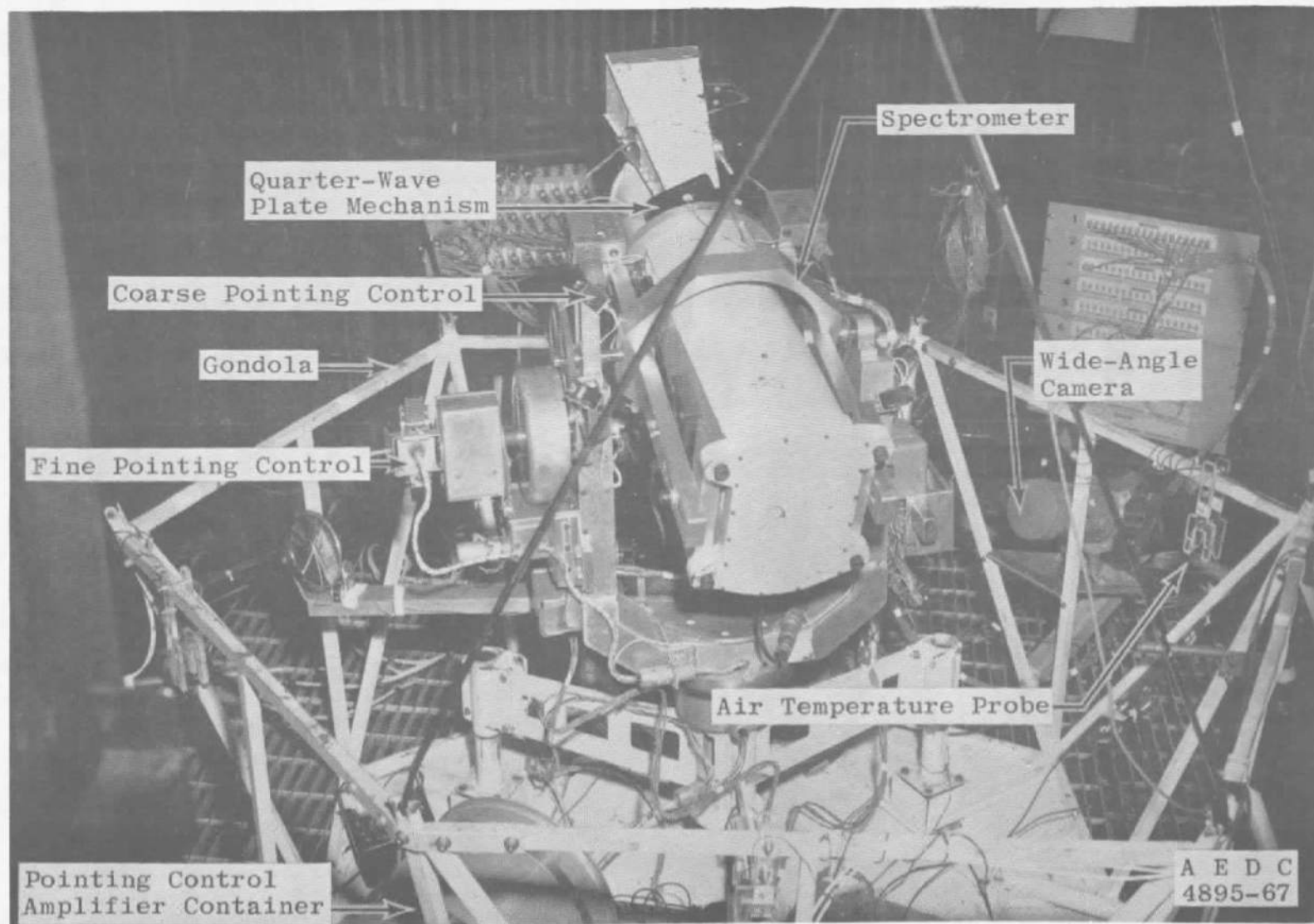


Fig. 1 Balloon Instrument Package

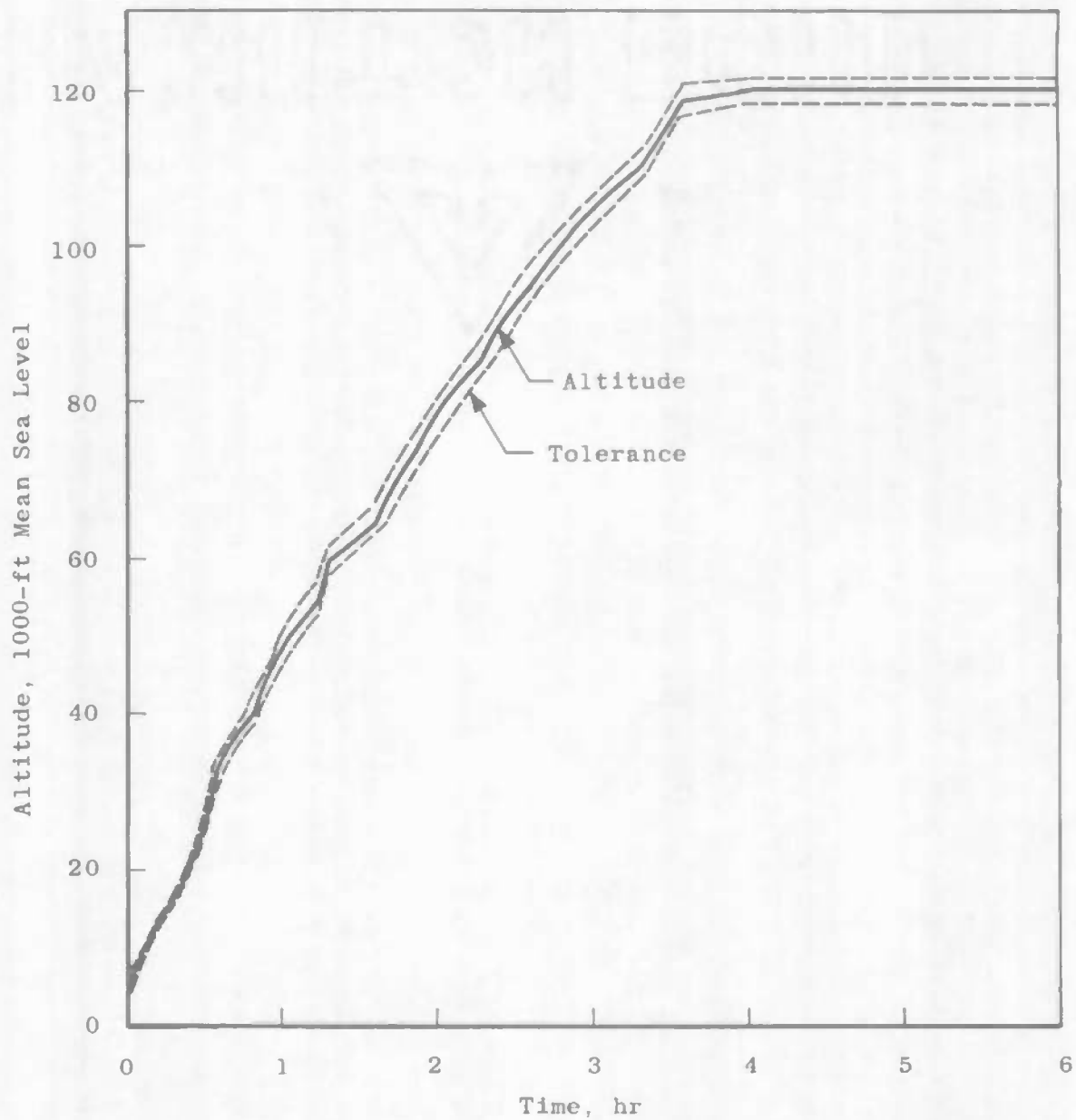


Fig. 2 Balloon Flight Altitude

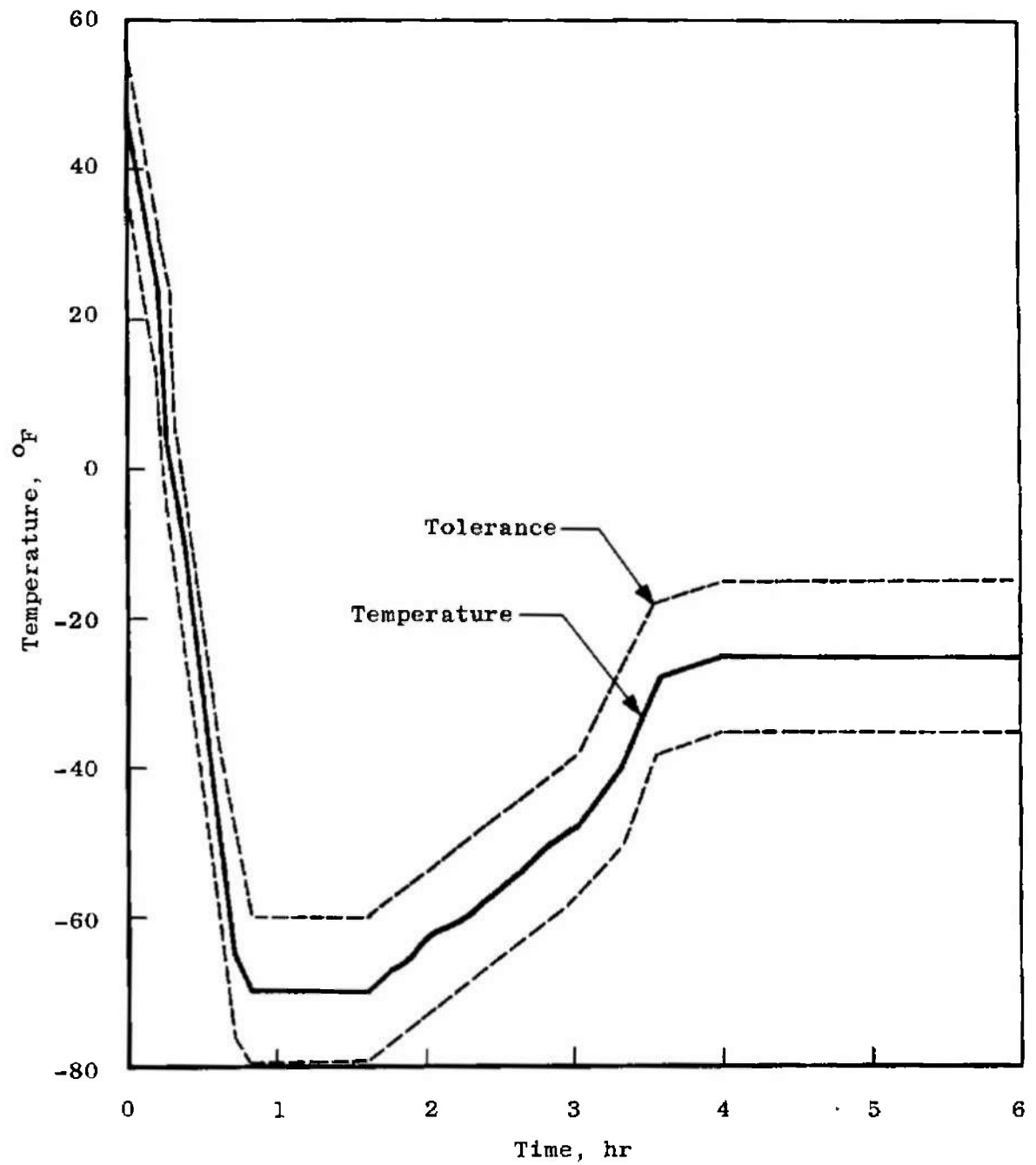
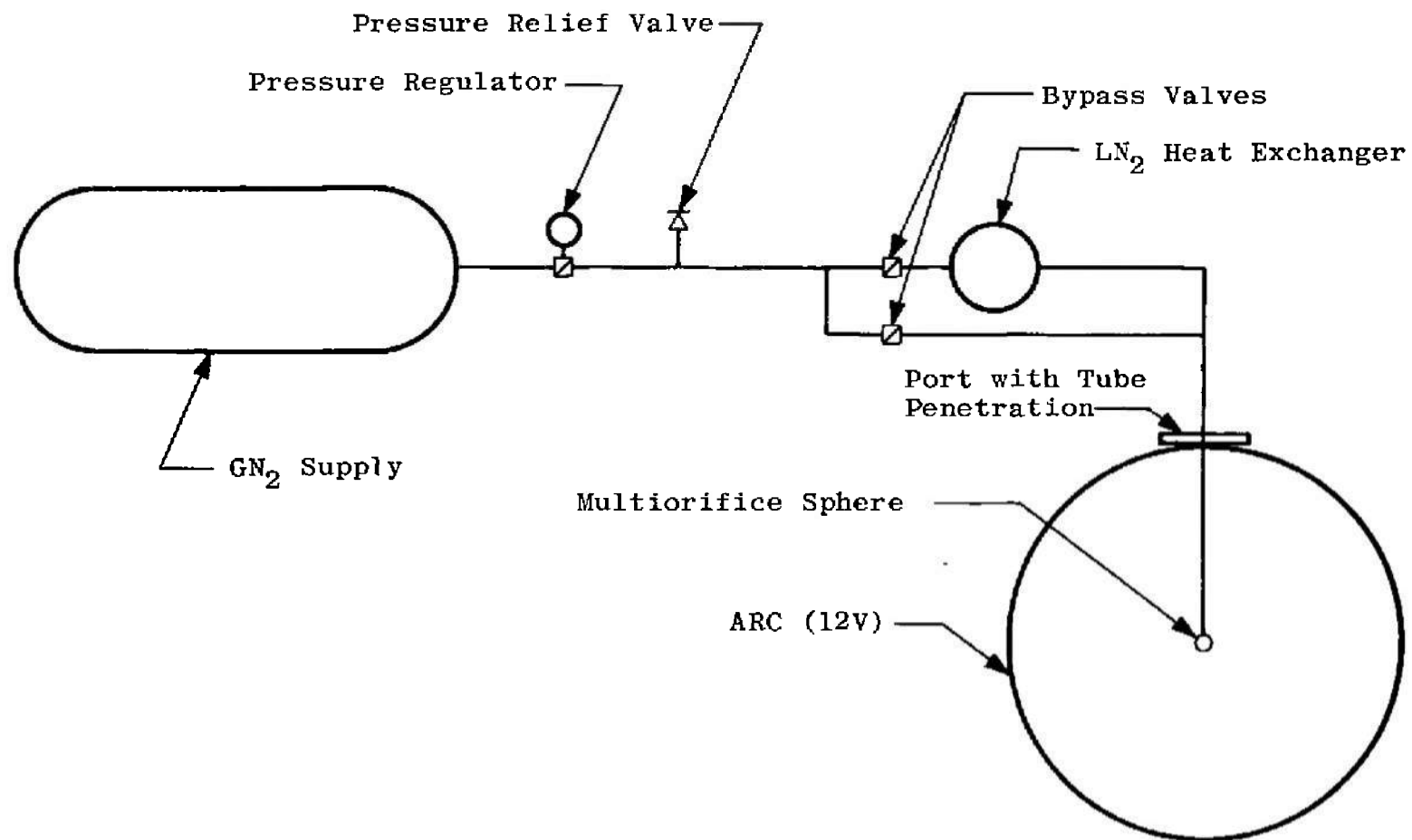
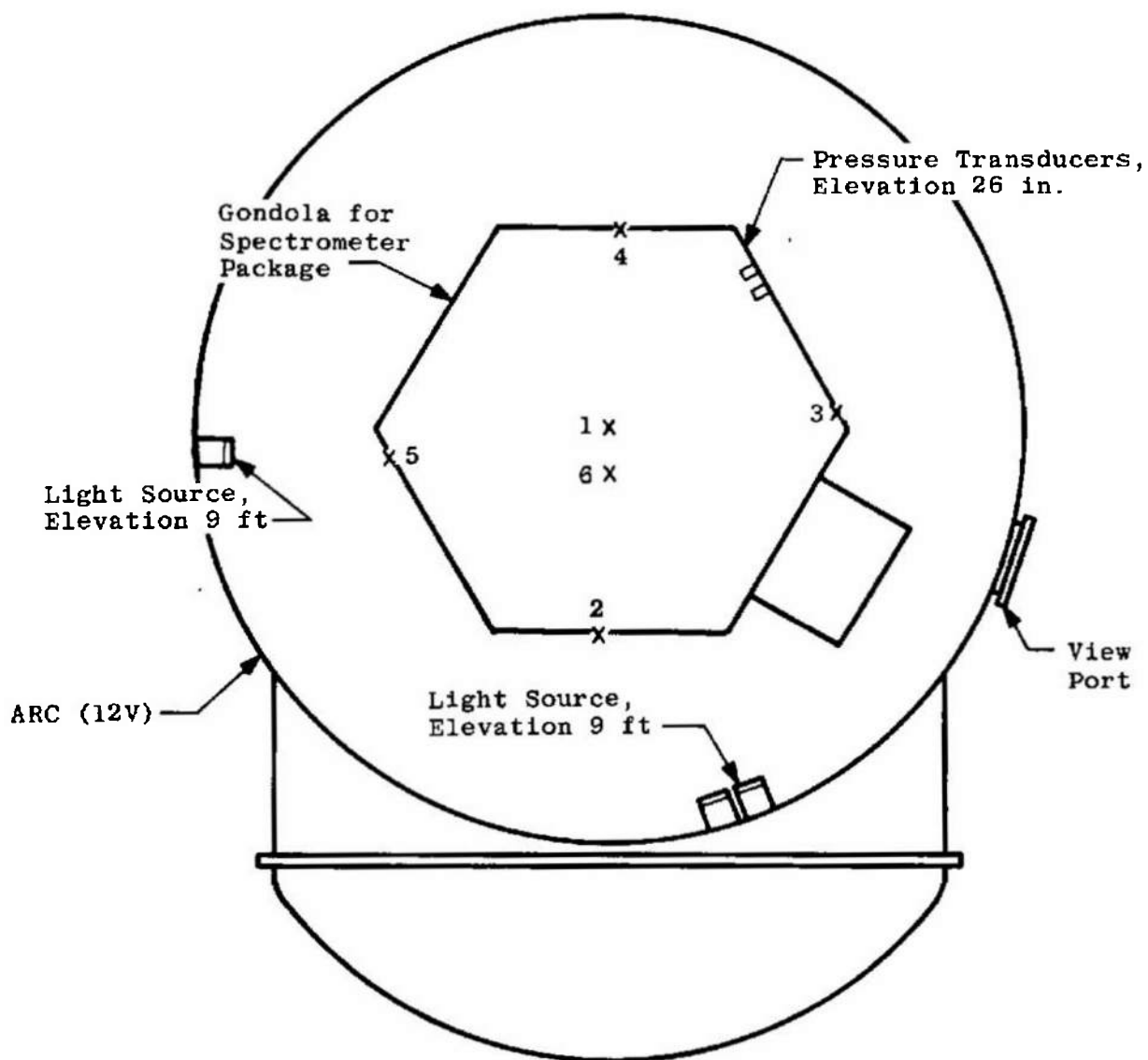


Fig. 3 Balloon Flight Temperature



Fig. 4 Aerospace Research Chamber (12V)

Fig. 5 Schematic of N₂ Inbleed



<u>Air Temperature Probe</u>	<u>Elevation, in.</u>
1	65
2, 3, 4, 5	23
6	6

Fig. 6 Test Schematic

Plexiglas® Support

Thermocouple Junction

9

A E D C
13982-66

Fig. 7 Air Temperature Probe

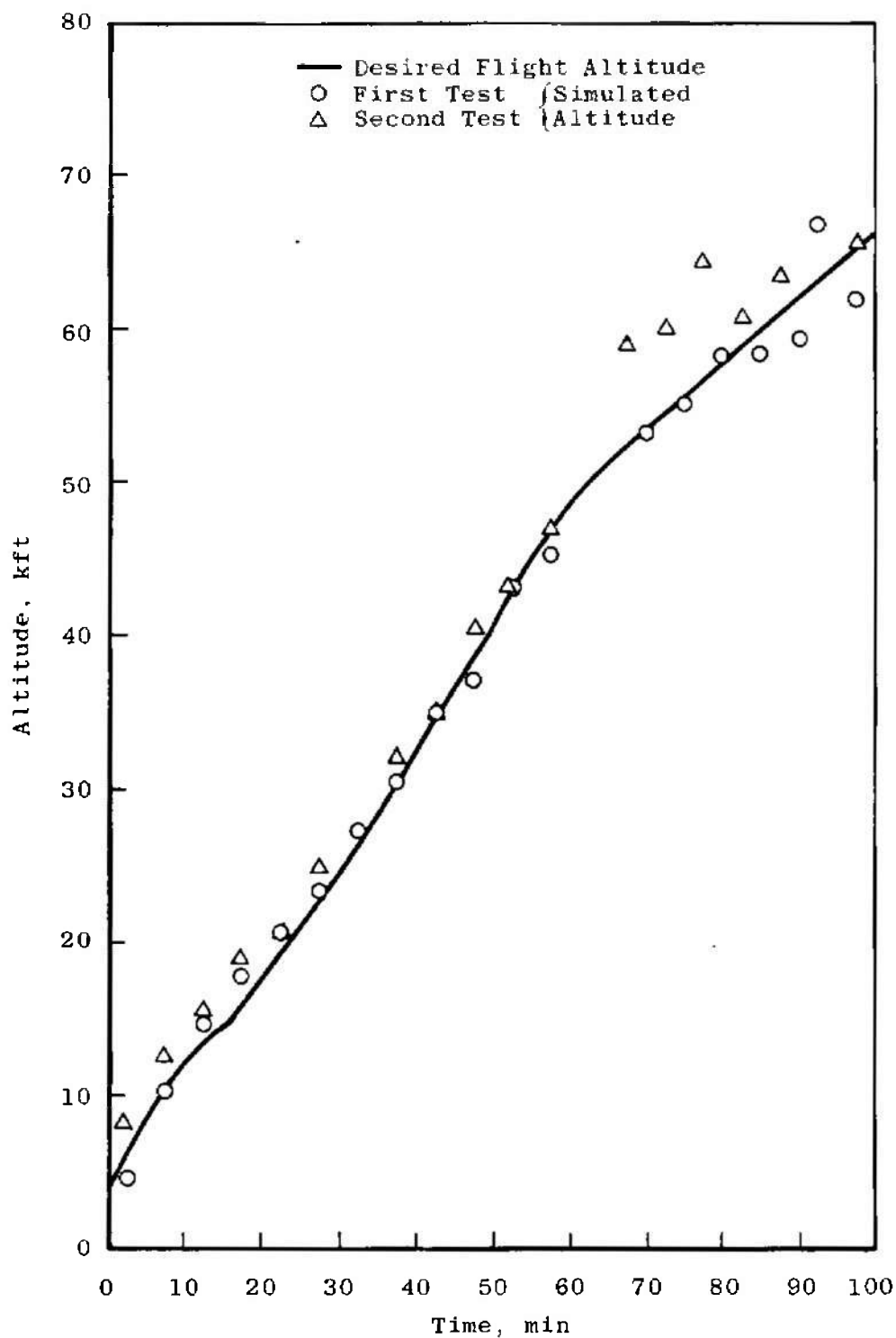


Fig. 8 Simulated Flight Test Altitude

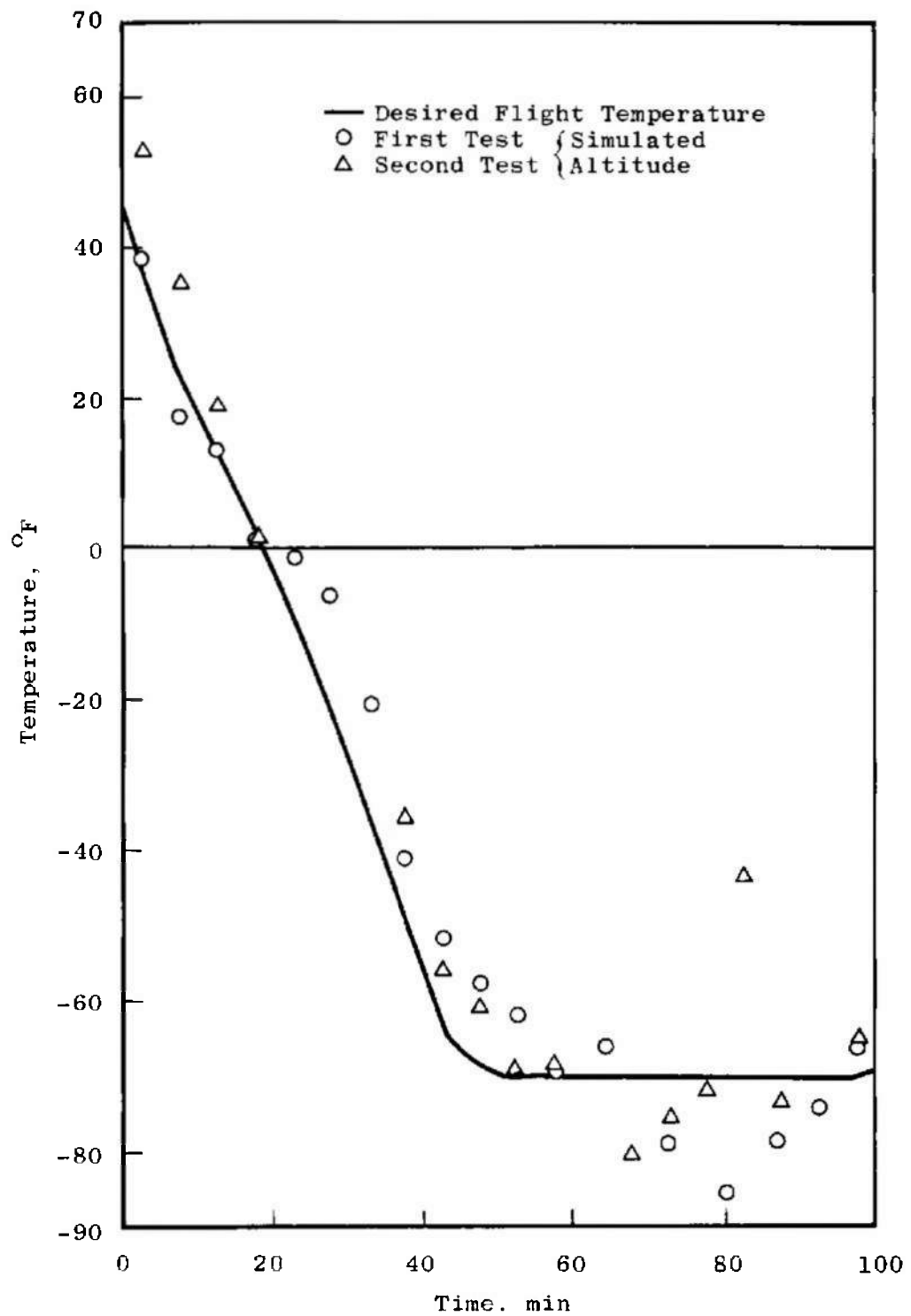


Fig. 9 Simulated Flight Test Temperature

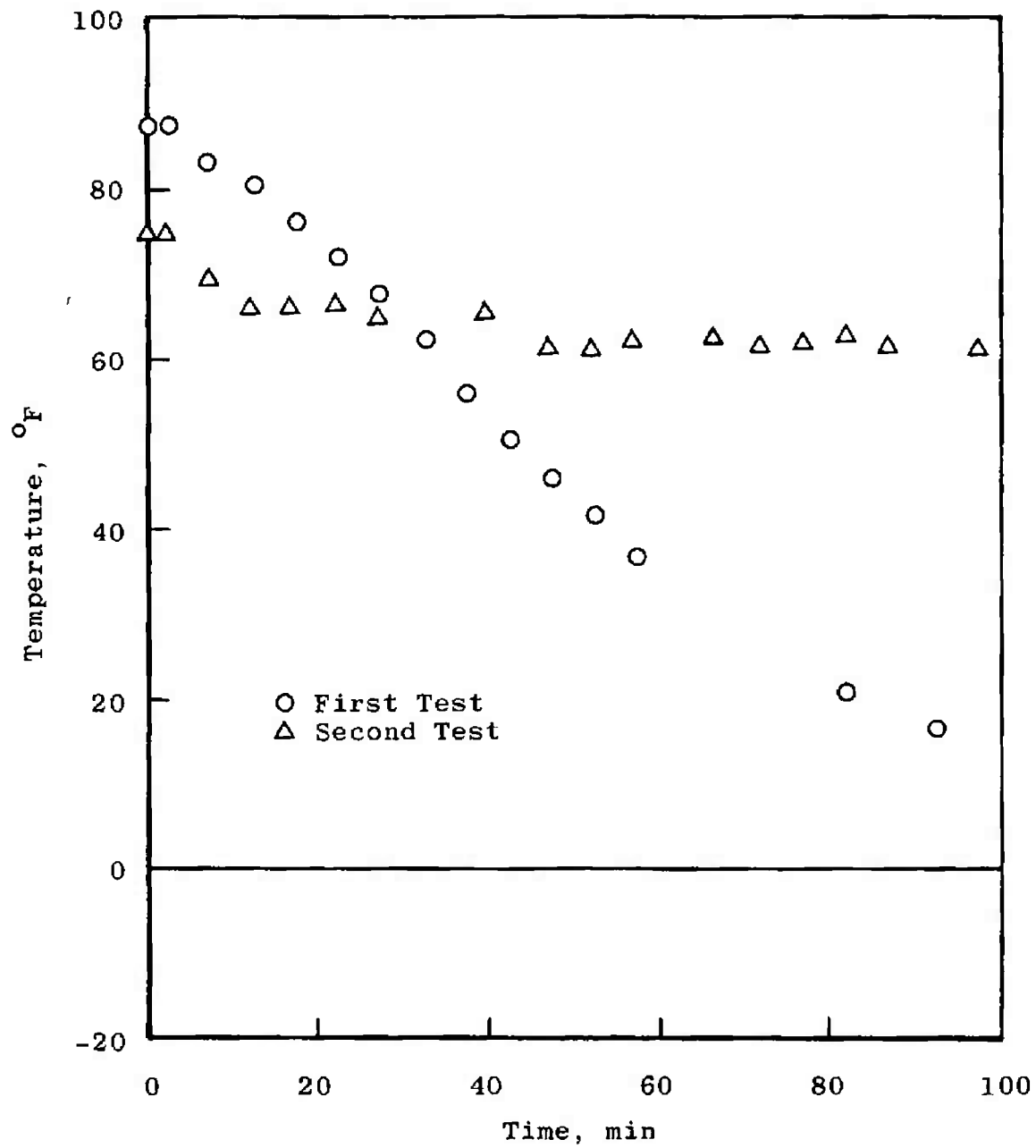


Fig. 10 Pointing Control Amplifier Temperature

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