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DFVLR/AEDC COOPERATIVE THERMAL TEST II

N. C. Latture

ARO, Inc.

May 1972

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NOTICES

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FOREWORD

The work reported herein was done at the request of Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), under Program Element 64719F. The Deutsche Forschungs- Und Versuchsansalt Fur Luft Und Raumfahrt (DFVLR) designed and fabricated the 10-cm-diam spherical test model.

The results presented were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the AEDC, AFSC, Arnold Air Force Station, Tennessee, under Contract F40600-72-C-0003. The tests were conducted on July 13 and 14, 1971, under ARO Project No. VR2236, data analysis was completed August 10, 1971, and the manuscript was submitted for publication on November 1, 1971.

This technical report has been reviewed and is approved.

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ABSTRACT

A 10-cm-diam calibration sphere was tested in a space simulation chamber under two different background conditions. In one case, the sphere was enclosed in a black liquid-nitrogen (LN_2) cooled shroud, while in the other case the sphere was exposed to the chamber walls which contain some sections not at LN_2 temperature. In both cases, the sphere was allowed to reach a stabilized temperature while exposed to one solar constant. The final stabilized temperatures were only 2°F (1.1°C) different, indicating that the "hot spots" in the chamber walls are not very significant for this type of test article. It is shown that they can be accounted for by computational techniques.

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SECTION I
INTRODUCTION

The DFVLR/AEDC Cooperative Test Program was initiated in August 1967. The purpose was to improve the understanding of thermal-vacuum simulation techniques at AEDC and DFVLR through mutual cooperation between the two facilities. The results of some of the work performed previously are presented in Refs. 1 through 4.

In some of this previous work, the effects of cryodeposits and uncooled wall sections were evaluated. The Aerospace Chamber (12V) at AEDC has liquid-nitrogen (LN_2) cooled walls. However, there are some wall sections which are not cooled to LN_2 temperature (77°K), and it was desirable to evaluate more fully the effects of these uncooled sections.

The results presented herein are from a thermal balance test, using a 10-cm-diam hollow sphere with a thermocouple mounted in the center in a smaller sphere. The equilibrium temperature established while irradiating the sphere with one solar constant was used as a measure of the simulation achieved. Two tests were performed to help determine the background simulation of the ARC 12V. In one test, the sphere was enclosed in a completely cooled LN_2 shroud, and in the other test, it was exposed to the 12V cryowalls, small portions of which are LN_2 cooled by conduction only. These conduction-cooled areas and their respective temperatures are described in Section IV.

SECTION II
APPARATUS

2.1 TEST MODEL

The 10-cm-diam sphere shown in Fig. 1 (Appendix I) was the model. The sphere was made of 0.04-mm-thick aluminum. It was designed and fabricated by DFVLR and painted black. The monitoring thermocouple was imbedded in a small sphere (0.5-cm-diam) which was supported by a small spider in the center of the large sphere. The α/ϵ ratio was 1.03 ± 0.02, where α is the amount of energy absorbed by the sphere surface and ϵ is the amount of energy emitted from the surface.

2.2 TEST CHAMBER

The ARC 12V is a stainless-steel vacuum chamber 12 ft in diameter and 35-ft high (Fig. 2). The lower portion of the chamber is lined with 380 ft^2 of liquid-nitrogen-cooled cryosurface which shields 120 ft of gaseous-helium-cooled surface that can be used to pump condensable gases. The top portion of the chamber houses the collimating mirror and entrance window for the off-axis solar simulator. For this test, one LN_2-cooled shield was placed in the top portion of the 12V to eliminate the major part of the warm chamber background. The chamber vacuum pumping system consists of a 750-cfm roughing pump, a 140-cfm forepump, a 750-cfm Roots blower, and a 50,000-liter/sec oil diffusion pump.

The solar simulator (Ref. 5) used to irradiate the test model is an off-axis system consisting of three basic components: a source lamp array, an optical integrating lens system, and a collimating mirror. The source is an array of seven 20-kw xenon arc lamps in elliptical reflectors. The radiation from the lamps passes through a quartz integrating lens unit in the chamber wall to a 10-ft-diam aluminized collimating mirror. A shutter mounted at the entrance window is used to interrupt the solar output. The mirror directs the beam down into the test volume. This system provides a beam of relatively uniform intensity (±4 percent) over the 2-ft-diam test volume. The measured beam decollimation is 1.84 deg.

For Test No. 1, the sphere was mounted by nylon strings on the major axis of the LN_2-cooled shroud 12-in. from the bottom of the shroud shown in Fig. 3. The shroud was 24 in. in inside diameter and 7 ft tall. For test No. 2, the shroud was removed, and the sphere was suspended with nylon string as shown in Fig. 1.

SECTION III
PROCEDURE

The sphere was installed in the LN_2-cooled shroud inside the ARC 12V. Instrumentation connections were made, and checkout of the system was conducted. A solar simulator calibration had been performed previously. The chamber was evacuated to test conditions (10^{-6} torr) and the LN_2-cooled shroud and chamber floor were cooled. The solar simulator was then set at one solar constant and maintained until the sphere attained an equilibrium temperature. The solar simulator was then shut off until the sphere cooled, and the cycle was repeated.

In the second test, the same operations were performed except the LN_2-cooled shroud was removed, and the chamber LN_2 walls were cooled. Two cycles were also performed for Test No. 2.

SECTION IV
RESULTS AND DISCUSSION

Figure 4 shows the location of thermocouples on the LN_2 shroud and identifies them by data points 1 through 16. The temperatures are tabulated in Table I (Appendix II). Figure 5 shows the location of thermocouples on the ARC 12V cryogenic system and identifies them by data points from 15 through 60. This figure also gives the sizes of the portions of the 12V that do not reach LN_2 temperatures. The temperatures are tabulated in Table II. Figure 6 shows the dimensions of the 12V chamber and identifies the alpha and epsilon values used in the calculations. Figure 7 is a plot of solar intensity and model temperature versus time during the prestabilization period. The experimental temperatures obtained with and without the cooled shroud differed by 2°F as shown in Table III.

The calculated stabilized temperature for the sphere enclosed in the LN_2-cooled shroud and irradiated with one solar constant was 49°F, and the temperature obtained in the 12V test was 53°F. Thus, the difference between the calculated and the measured temperature was 4 deg. Since there is an uncertainty in the α/ϵ for the sphere and the radiation from the solar simulator of perhaps 2 and 3 percent, respectively, this is easily within the expected error band.

The calculated temperature for the 12V background test, using the temperatures and the alpha and epsilon values shown in Figs. 5 and 6, was 54°F while the test temperature was 55°F. In this case, the difference between calculated and measured values was only one degree. There is the possibility that the solar simulator irradiance output was actually higher although the measuring equipment indicated the same setting. However, it is also possible that the contributed heat load from the uncooled wall panels was less than computed, and hence the measured temperature increased less than anticipated. Thus, it seems that the calculation technique which defines the effects of the wall panels is conservative; i.e., the average temperature of the uncooled panels may be lower than the temperature indicated by the single thermocouples which are attached to the centers of the panels. This would cause the actual contribution from "hot spots" to be lower than predicted. Thus, the present calculation overestimates the effects of the uncooled panels.

Table III illustrates the effect on a final stabilized temperature of changing the solar intensity by 3 percent and also by changing alpha (α) of the sphere by 3 percent.

SECTION V
CONCLUSIONS

The calculated stabilized temperature of the sphere enclosed in the LN_2-cooled shroud differed by 4°F with the experimental value. Table III shows that if the solar intensity calibration were in error by 3 percent the temperature would be off by 4°F, or if the α/ϵ value is incorrect by 3 percent, then the temperature would be off by 3.5°F. Since there is about 3-percent uncertainty in each of these factors, the agreement is reasonable.

The temperature measured when the shroud was not present indicated a rise of 2°F in the temperature of the sphere, but this rise was not as much as calculated, implying that the contribution of the chamber "hot spots" was overestimated. Their effect appears to be overestimated by about 50 percent.

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2. Mills, D. W., Jr. and Smith, A. M. "Effect of Reflections from CO_2 Cryopanel Deposits on the Thermal Balance of a Test Model in a Space Simulation Chamber." AEDC-TR-69-226 (AD862780), December 1969.

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APPENDIXES

I. ILLUSTRATIONS
II. TABLES

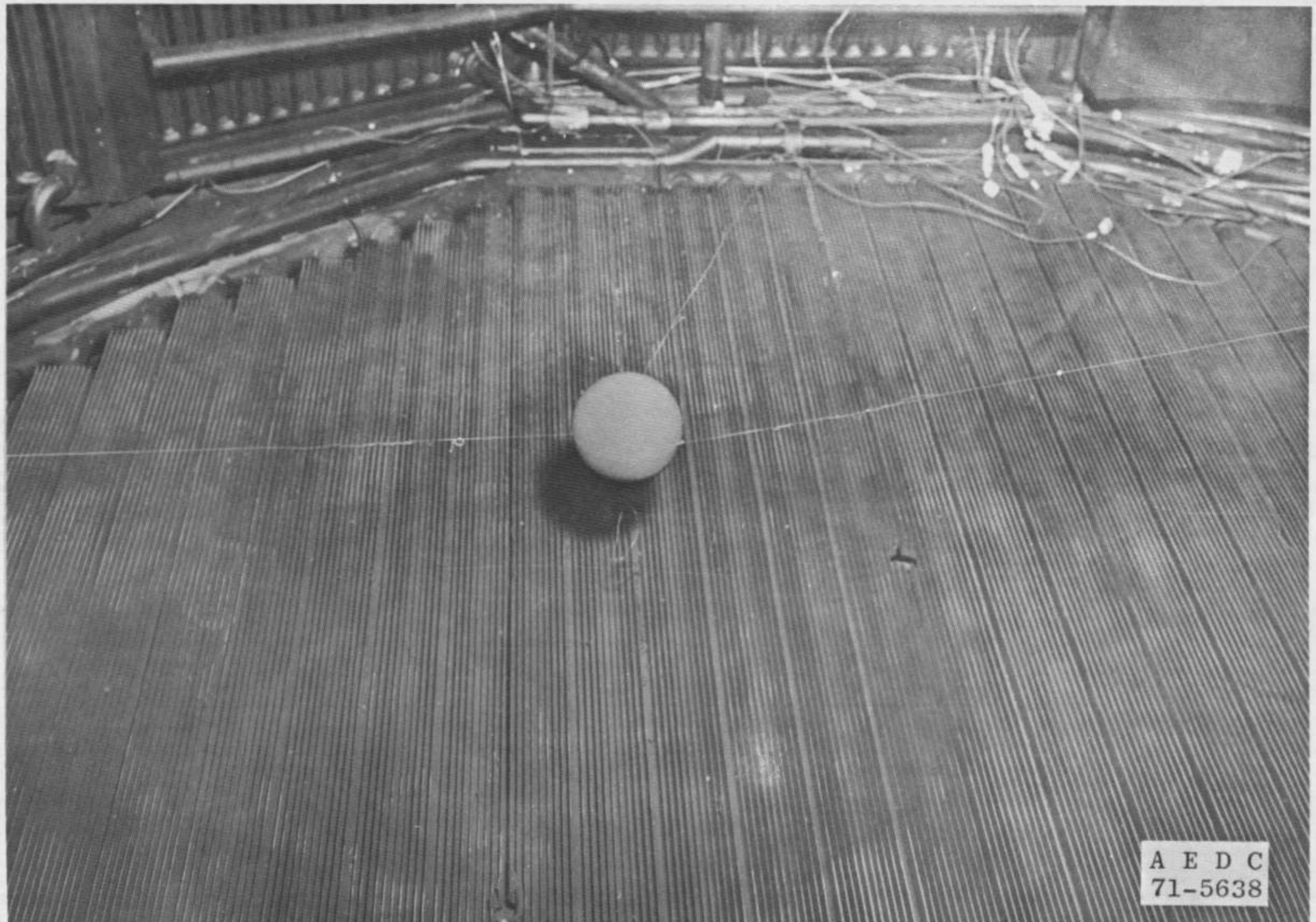


Fig. 1 10-cm-diam Sphere Test Model in 12V Chamber

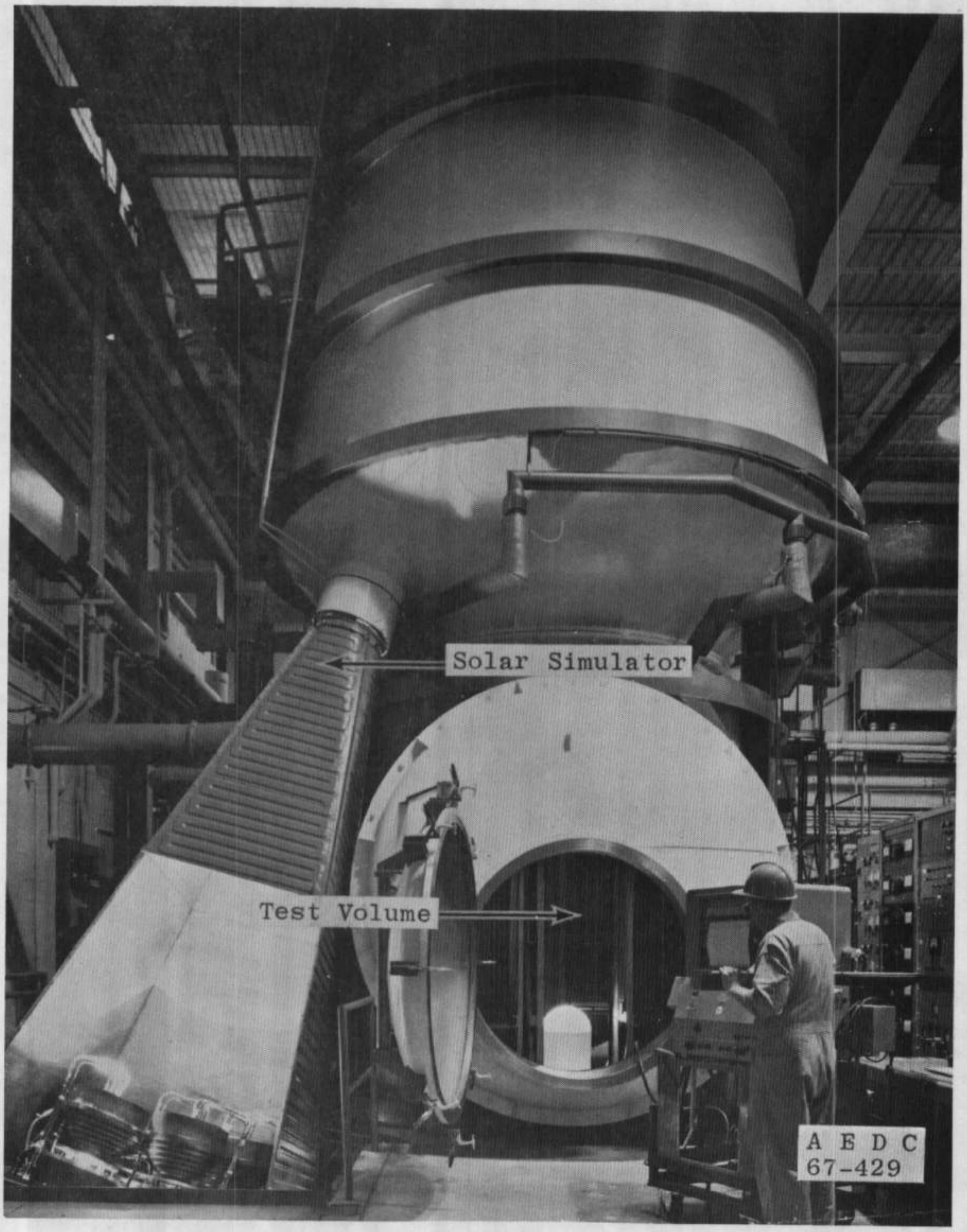


Fig. 2 Aerospace Chamber (12V)

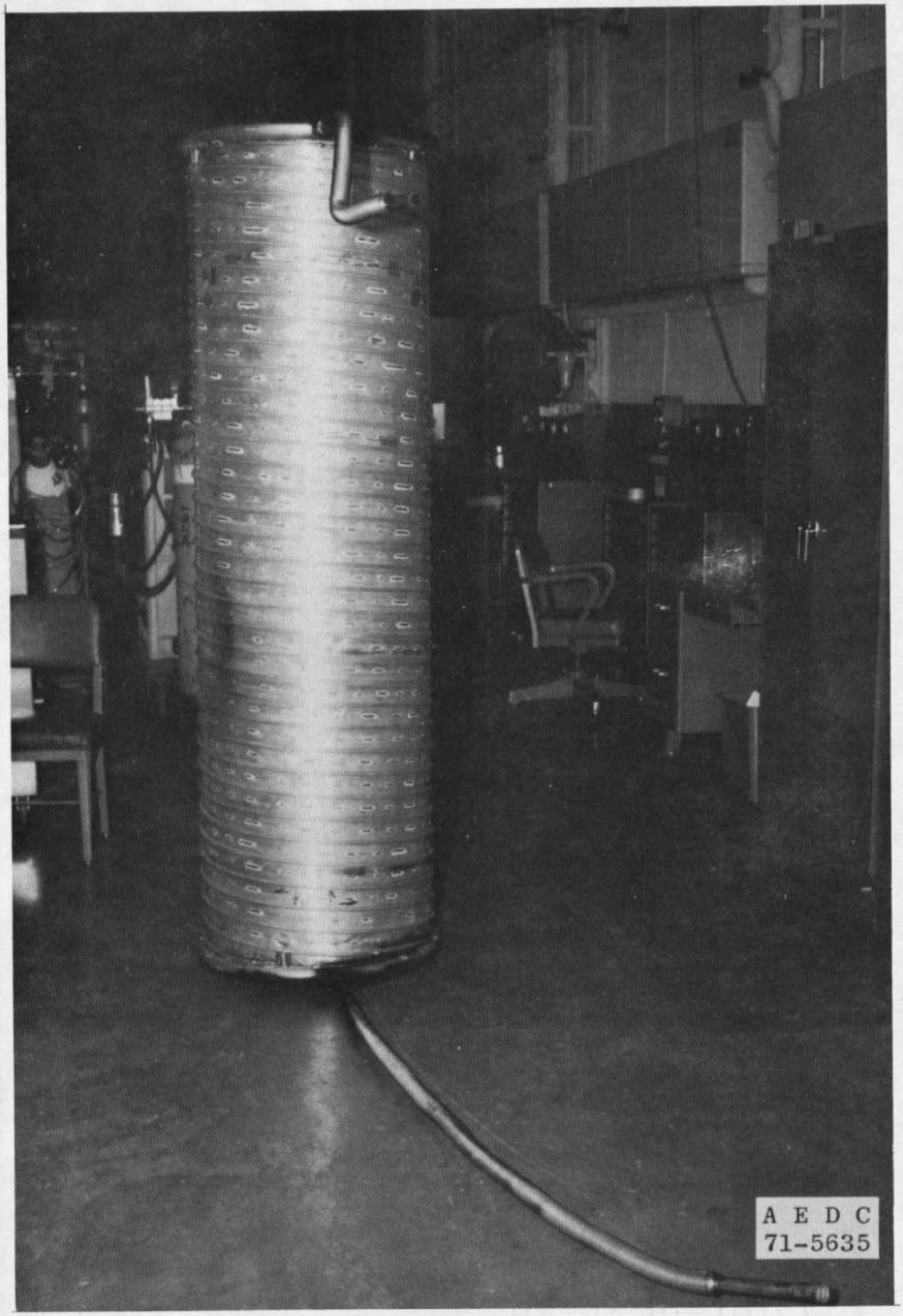


Fig. 3 LN_2-Cooled Shroud Used in Test No. 1

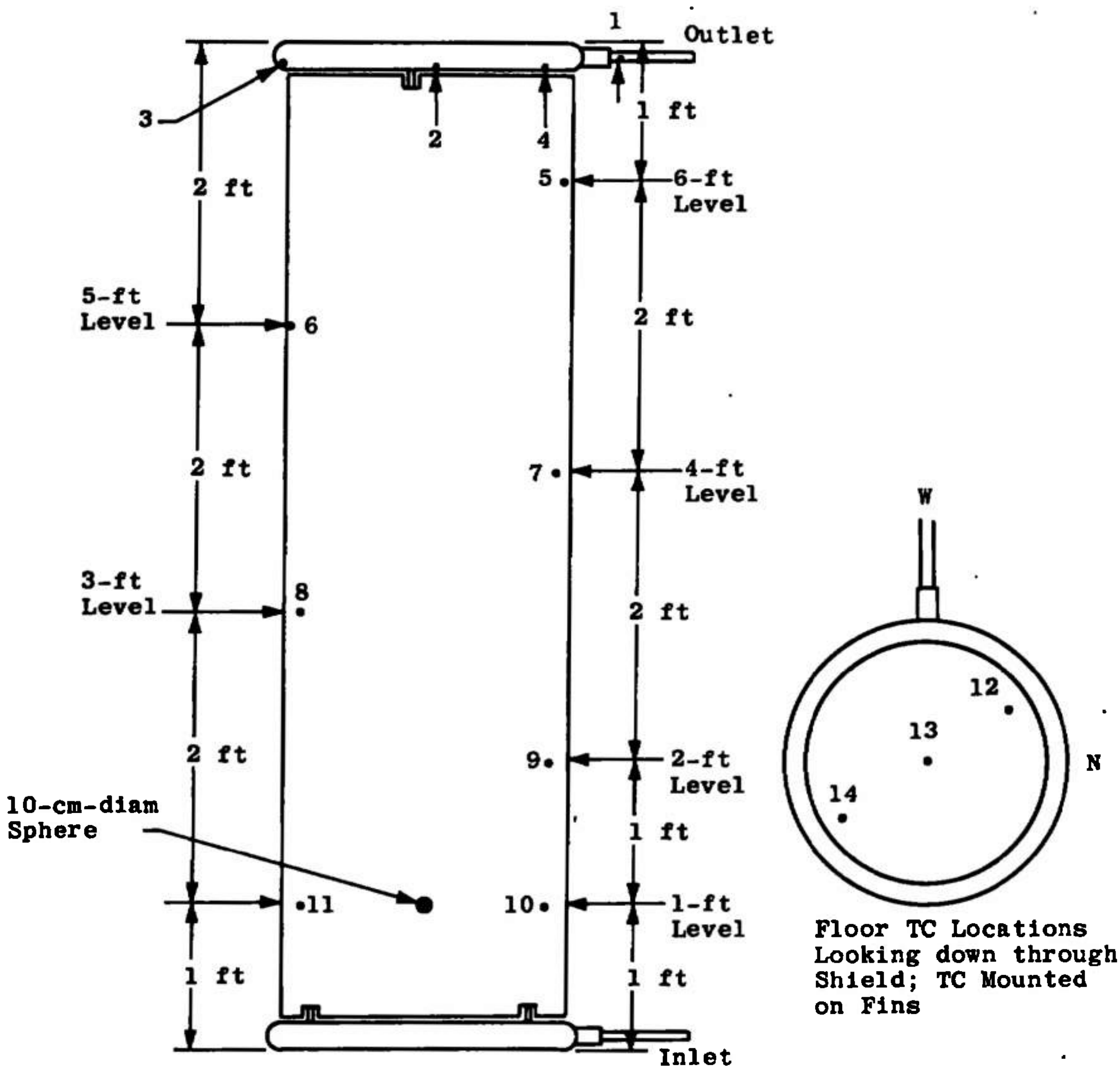


Fig. 4 Data Point Locations on LN_2-Cooled Shroud

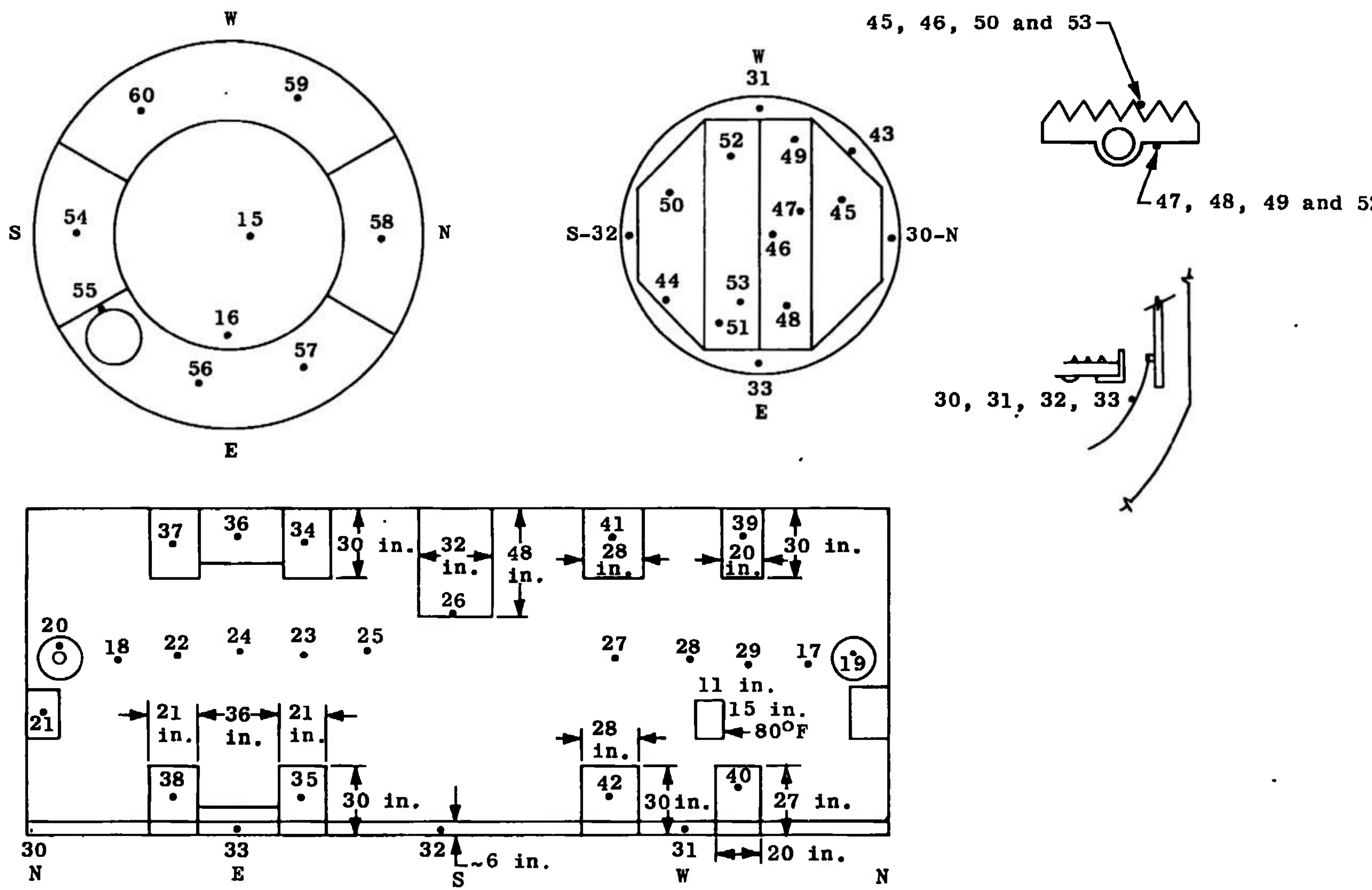


Fig. 5 Rollout of 12V Cryosystem Showing Data Point Locations and Size of "Hot Spots" in Chamber

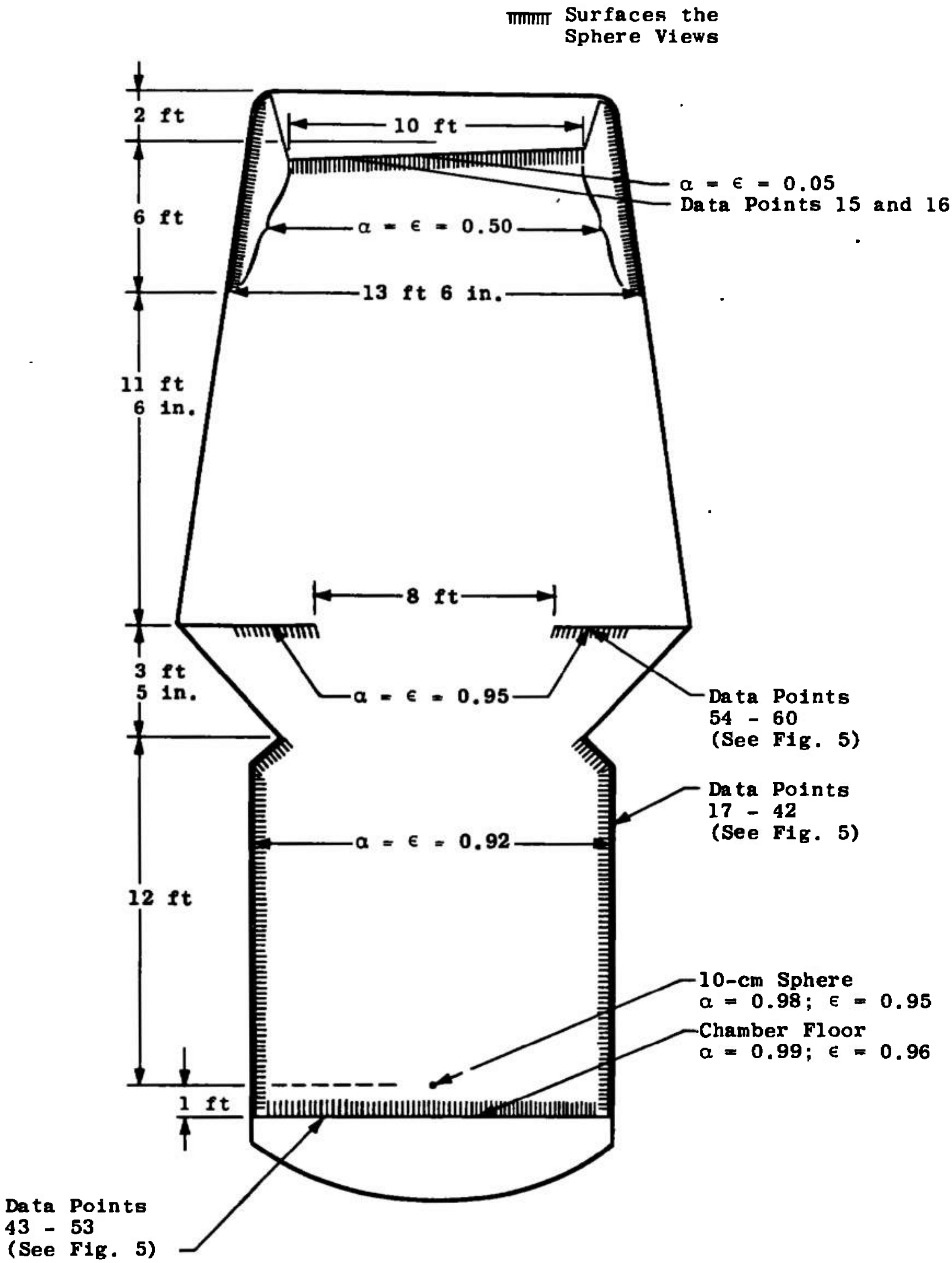


Fig. 6 Outline of ARC 12V Showing α and ϵ Values for Different Parts of the Chamber

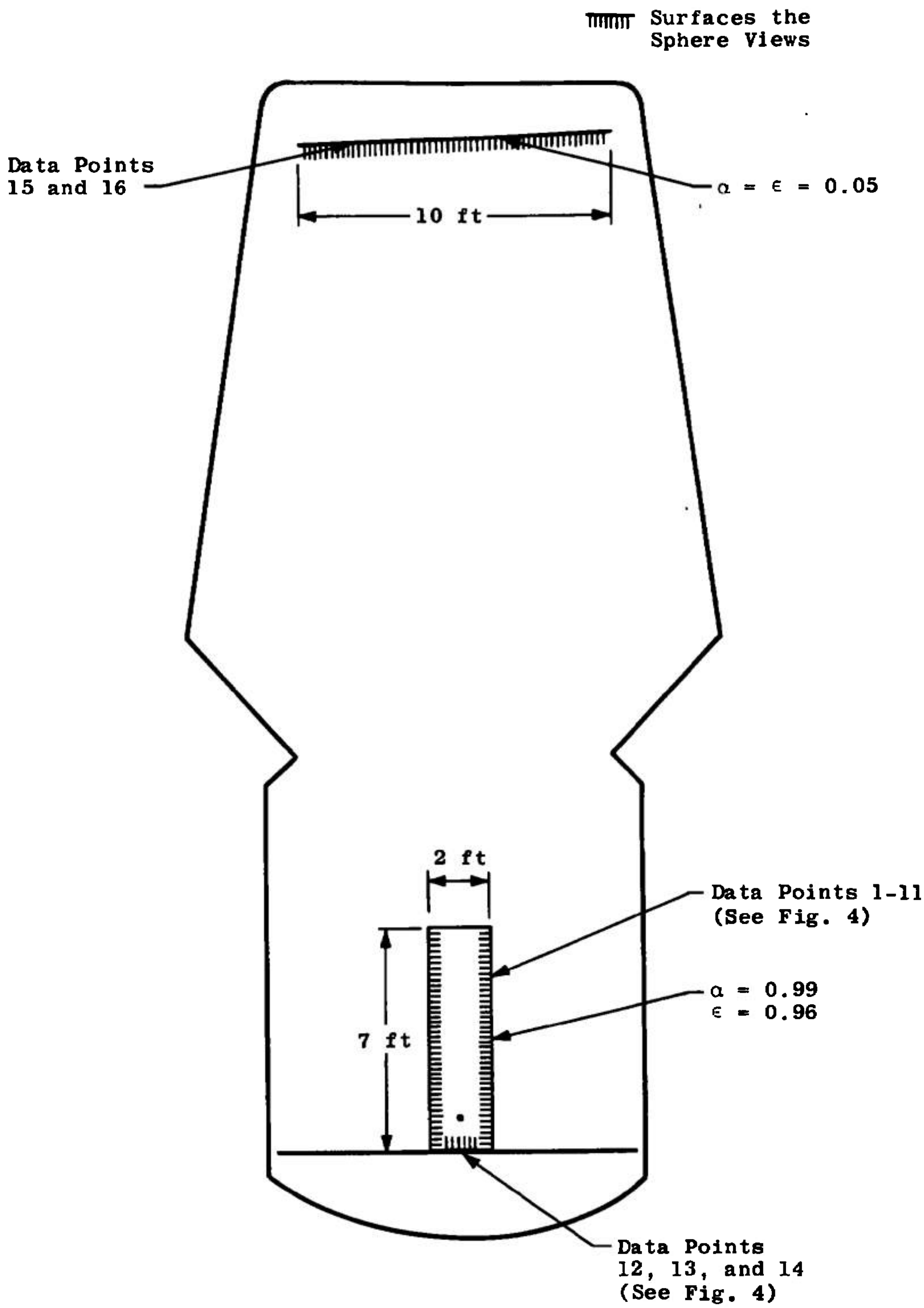
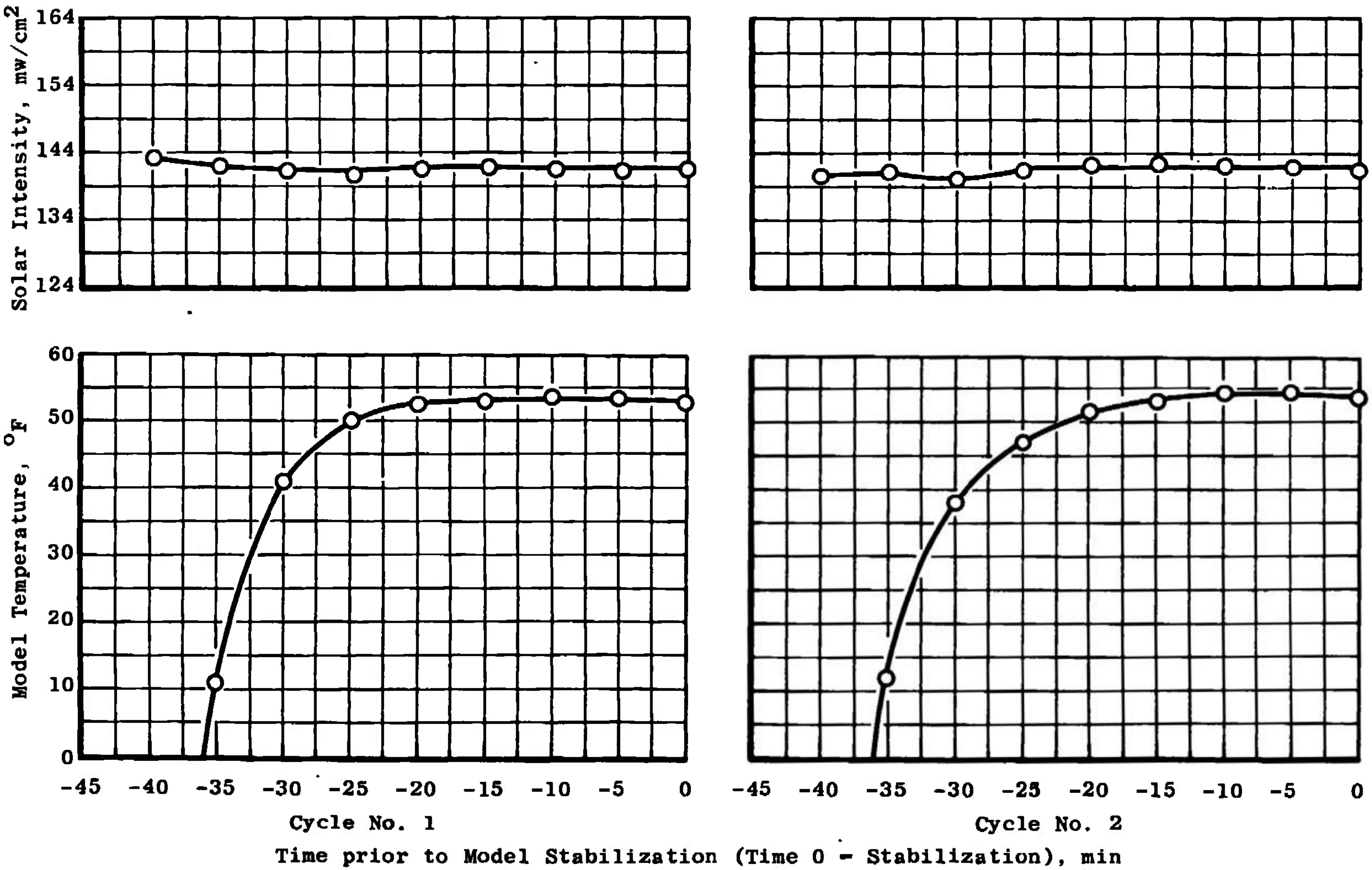
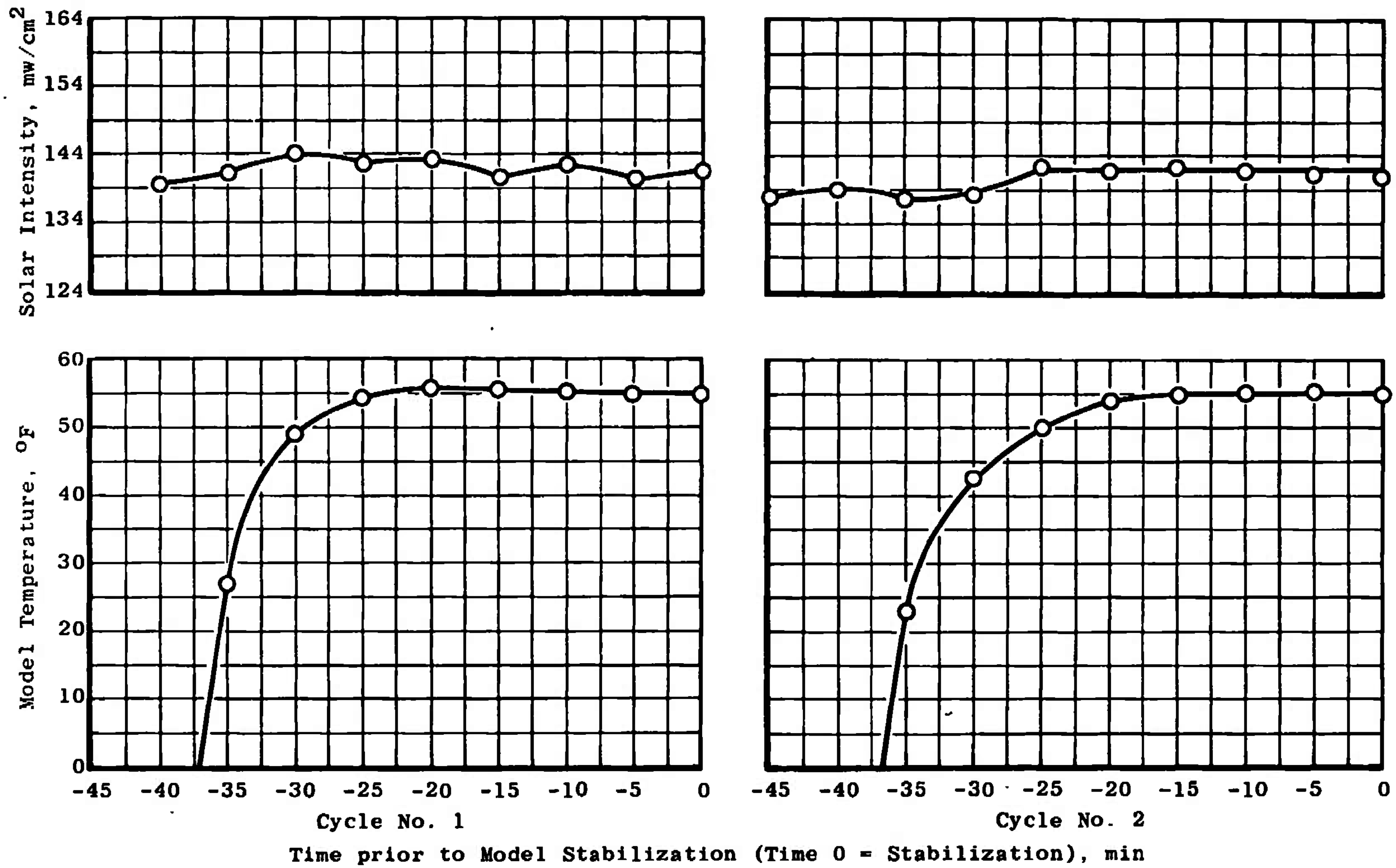


Fig. 6 Concluded



a. Test No. 1

Fig. 7 Solar Intensity and Model (Sphere) Temperature



b. Test No. 2
Fig. 7 Concluded

TABLE I
THERMOCOUPLE LOCATIONS AND TEMPERATURES FOR TEST NO. 1

Thermocouple Location*	Data Point	Temperature, °F	
		Cycle No. 1	Cycle No. 2
LN_2 Outlet	1	-320	-320
Top LN_2 Manifold	2	-313	-308
Top LN_2 Manifold	3	-320	-320
Top LN_2 Manifold	4	-320	-320
6-ft Elevation on Shroud	5	-320	-320
5-ft Elevation on Shroud	6	-320	-320
4-ft Elevation on Shroud	7	-320	-320
3-ft Elevation on Shroud	8	-317	-319
2-ft Elevation on Shroud	9	-313	-316
1-ft Elevation on Shroud	10	-310	-312
1-ft Elevation on Shroud	11	-320	-320
LN_2 Floor under Shroud	12	-310	-310
LN_2 Floor under Shroud	13	-314	-313
LN_2 Floor under Shroud	14	-312	-307
Solar Mirror North Center	15	92	92
Solar Mirror East Side	16	94	96
Model (Sphere) Temperature	61	53.0	53.8

*See Fig. 6 for Schematic Location.

TABLE II
THERMOCOUPLE LOCATIONS AND TEMPERATURES FOR TEST NO. 2

Thermocouple Location*	Data Point	Temperature, °F	
		Cycle No. 1	Cycle No. 2
Solar Mirror, North Center	15	94	96
Solar Mirror, East Side	16	96	99
North Cryopanel, Left Back	17	-306	-310
North Cryopanel, Right Back	18	-317	-319
West View Port	19	-307	-308
East View Port	20	-306	-305
Radiometer Shield	21	-312	-311
East Cryopanel, Left Back	22	-310	-315
East Cryopanel, Right Back	23	-285	-294
East Cryopanel, Door	24	-317	-317
South Cryopanel, Left Back	25	-290	-296
Diffusion Pump Vane Inlet	26	-239	-245
West Cryopanel, Left Back	27	-320	-320
West Cryopanel, Mid Front	28	-273	-296
Scavenger, West Section	29	-310	-313
Shield Floor-to-Wall North	30	-92	-100
Shield Floor-to-Wall West	31	-104	-117
Shield Floor-to-Wall South	32	-116	-79
Shield Floor-to-Wall East	33	-91	-100
Shield Top Chamber at 80 deg	34	-36	-42
Shield Bottom Chamber at 80 deg	35	-37	-45
Shield Top Chamber at 90 deg	36	-47	-58
Shield Top Chamber at 100 deg	37	-34	-43
Shield Bottom Chamber at 100 deg	38	-33	-41
Shield Top Chamber at 250 deg	39	-41	-53
Shield Bottom Chamber at 250 deg	40	-168	-180
Shield Top Chamber at 290 deg	41	-49	-64
Shield Bottom Chamber at 290 deg	42	-298	-300
Floor Panel Ring Hardware N. W.	43	-228	-238
Floor Panel Ring Hardware S. E.	44	-230	-239

*See Fig. 6 for Schematic Location.

TABLE II (Concluded)

Thermocouple Location*	Data Point	Temperature, °F	
		Cycle No. 1	Cycle No. 2
Floor Panel East Panel C Bottom	45	-308	-317
Floor Panel Center Panel B Bottom	46	-311	-316
Floor Panel Center Panel B Bottom	47	-303	-304
Floor Panel East Panel B Bottom	48	-306	-309
Floor Panel West Panel B Bottom	49	-305	-308
Floor Panel West Panel D Bottom	50	-319	-320
Floor Panel East Panel C	51	-303	-305
Floor Panel West C Fin	52	-302	-305
Floor Panel East C Fin	53	-308	-311
Bottom Solar Shield 0 deg, zone 0 deg	54	-307	-309
Bottom Solar Shield 90 deg, zone 40 deg	55	-6	-118
Bottom Solar Shield 90 deg, zone 80 deg	56	-87	-306
Bottom Solar Shield 90 deg, zone 130 deg	57	-255	-266
Bottom Solar Shield 180 deg, zone 180 deg	58	-255	-267
Bottom Solar Shield 270 deg, zone 270 deg	59	-302	-304
Bottom Solar Shield 270 deg, zone 320 deg	60	-294	-297
Model (Sphere) Temperature	61	55	54.8

*See Fig. 6 for Schematic Location.

TABLE III
CALCULATED SPHERE TEMPERATURE OBTAINED BY CHANGING ALPHA (α) AND/OR SOLAR INTENSITY

Sphere Stabilized Temperatures in LN_2-Cooled Shroud

Sphere α	Sphere ϵ	Solar Intensity, mw/cm^2	Calculated Temperature, °F	Experimental Temperature, °F	Temperature Difference, °F
0.98	0.95	140	49	53	4
0.95	0.95	140	45.5		
0.98	0.92	140	52.5		
0.98	0.95	144	53		

Sphere Stabilized Temperatures in ARC 12V.

Sphere α	Sphere ϵ	Solar Intensity, mw/cm^2	Calculated Temperature, °F	Experimental Temperature, °F	Temperature Difference, °F
0.98	0.95	140	54	55	1
0.95	0.95	140	50		
0.98	0.92	140	57.5		
0.98	0.95	144	58		

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13. ABSTRACT

A 10-cm-diam calibration sphere was tested in a space simulation chamber under two different background conditions. In one case, the sphere was enclosed in a black liquid-nitrogen (LN_2) cooled shroud, while in the other case the sphere was exposed to the chamber walls which contain some sections not at LN_2 temperature. In both cases, the sphere was allowed to reach a stabilized temperature while exposed to one solar constant. The final stabilized temperatures were only 2°F (1.1°C) different, indicating that the "hot spots" in the chamber walls are not very significant for this type of test article. It is shown that they can be accounted for by computational techniques.

14. KEY WORDS	LINK A		LINK B		LINK C	
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solar simulation						
temperature measurements						

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