

UNCLASSIFIED

AD NUMBER
AD475243
LIMITATION CHANGES
TO: Approved for public release; distribution is unlimited.
FROM: Distribution authorized to U.S. Gov't. agencies and their contractors; Critical Technology; DEC 1965. Other requests shall be referred to Arnold Engineering Development Center, Arnold AF Station, TN. This document contains export-controlled technical data.
AUTHORITY
AEDC ltr, 1 May 1972

THIS PAGE IS UNCLASSIFIED

AEDC-TR-65-264

**ARCHIVE COPY
DO NOT LOAN**

by:



VACUUM TESTING OF EXPANDABLE SELF-RIGIDIZING STRUCTURES

**N. C. Latture
ARO, Inc.**

PROPERTY OF U. S. AIR FORCE
AEDC LIBRARY
AF 40(600)1200

December 1965

~~This document is subject to special export controls
and each transmittal to foreign governments or foreign
nationals may be made only with prior approval of
Arnold Engineering Development Center.~~

This document has been approved for public release
and sale; its distribution is unlimited. *per DDC-TAB-72-9, 1 May 72*

**AEROSPACE ENVIRONMENTAL FACILITY
ARNOLD ENGINEERING DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
ARNOLD AIR FORCE STATION, TENNESSEE**



NOTICES

When U. S. Government drawings specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise, or in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Qualified users may obtain copies of this report from the Defense Documentation Center.

References to named commercial products in this report are not to be considered in any sense as an endorsement of the product by the United States Air Force or the Government.

VACUUM TESTING OF EXPANDABLE
SELF-RIGIDIZING STRUCTURES

N. C. Latture
ARO, Inc.

~~This document is subject to special export controls
and each transmittal to foreign governments or foreign
nationals may be made only with prior approval of
Arnold Engineering Development Center.~~

This document has been approved for public release
and sale, its distribution is unlimited. *per DDC-TAB-72-9, 1 May 72*

FOREWORD

The work reported herein was done at the request of the Air Force Aero-Propulsion Laboratory (APL), Research and Technology Division (RTD), Air Force Systems Command (AFSC), Wright-Patterson Air Force Base, Ohio under Program Element 62405214, Project 8170.

The expandable, self-rigidizing structures tested for APL were designed and fabricated by GCA Viron Division, division of GCA Corporation, Minneapolis, Minnesota, under Contract AF33(615)-2115.

The results of tests presented were obtained by ARO, Inc. (a subsidiary of Sverdrup and Parcel, 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 July 14 to August 19, 1965 under ARO Project No. ST0520, and the manuscript was submitted for publication on November 18, 1965.

This technical report has been reviewed and is approved.

William D. Clement
Major, USAF
AF Representative, AEF
DCS/Test

Jean A. Jack
Colonel, USAF
DCS/Test

ABSTRACT

Four expandable, self-rigidizing structures were impregnated with a water setting resin and packaged for deployment in a vacuum of 10^{-5} torr while exposed to 77°K cold walls in a space environmental chamber. The high pumping speeds available with this chamber permitted the removal of the large gas loads from the structure while maintaining test pressures of 10^{-5} torr. Water was used as a catalyst, and infrared heat lamps were used to maintain temperature control of the structures. Deployment was completely successful on three structures and partially successful on one. Rigidization of all four structures was successful.

CONTENTS

	<u>Page</u>
ABSTRACT.	iii
I. INTRODUCTION	1
II. APPARATUS	1
III. PROCEDURE	3
IV. RESULTS AND DISCUSSION	4
V. CONCLUSIONS	7

ILLUSTRATIONS

Figure

1. Aerospace Research Chamber (12V).	9
2. ARC (12V) Performance	10
3. Packaged and Deployed 1/6-Scale Model, MOL Type	11
4. Model 2 Mounted on Load Cell	12
5. Model 4 Test Configuration.	13
6. Model 3 Resin Impregnation	14
7. Packaging Model after Impregnation.	15
8. Packaged Model in Test Chamber.	16
9. Model 3 Partially Deployed.	17
10. Model 3 Completely Deployed	18
11. Model 1 Chamber Pressure	19
12. Model 1 Weight Loss	20
13. Model 1 Temperature	21
14. Model 1 after Rigidization	22
15. Model 2 Chamber Pressure	23
16. Model 2 Weight Loss	24
17. Model 2 Temperature	25
18. Model 2 after Rigidization	26

<u>Figure</u>		<u>Page</u>
19.	Model 3 Chamber Pressure.	27
20.	Model 3 Weight Loss.	28
21.	Model 3 Temperature	29
22.	Models 3 and 4 after Rigidization	30
23.	Model 4 Chamber Pressure	31
24.	Model 4 Weight Loss.	32
25.	Model 4 Temperature	33

SECTION I INTRODUCTION

Expandable structures are an important part of the manned space program.¹ All variations of this concept are characterized by a packaged structure many times smaller than its deployed configuration.

This report covers the testing of inflatable, self-rigidizing structures which are characterized by a fabric substrate. The fabric is woven or assembled into a sandwich construction, impregnated with resin, and packaged for deployment. Four 1/6-scale model Manned Orbiting Laboratory (MOL)-type structures were tested for GCA Viron Division, a division of GCA Corporation, in the Aerospace Research Chamber (ARC) (12V), Aerospace Environmental Facility (AEF), AEDC. The test objective was to determine if the models would deploy and rigidize in a simulated space environment and to record the deployment and rigidization with motion photography.

SECTION II APPARATUS

2.1 TEST CHAMBER

The ARC (12V) (Fig. 1) is a stainless steel space simulation chamber 12 ft in diameter and 14 ft in height. The chamber is completely lined with a liquid-nitrogen-cooled liner which provides a 77°K black heat sink. The chamber pumping system consists of a 500-cfm roughing pump, 140-cfm mechanical fore pump, 32-in. oil diffusion pump and valve, and 120 ft² of 20°K cryosurface. Chamber pumping speeds for various gases are shown in Fig. 2. Ultimate pressure of this chamber is 10⁻⁹ torr.

The chamber is equipped with 16 channels of heat flux equipment which can be programmed to simulate heat loads on a vehicle surface for desired test orbits and trajectories. A solar simulator is now being built which will produce a uniform intensity over an 8-ft-diam area.

¹"Aerospace Expandable Structures Conference Transactions." Air Force Aero-Propulsion Laboratory (AD432006), October 23-24, 1963, Dayton, Ohio.

2.2 SCALE MODEL MOL-TYPE STRUCTURE

The test structure in both the packaged and deployed positions is shown in Fig. 3. The model consists of two epoxy domed halves 10 in. deep and 20 in. in diameter joined by a fabric substrate center section. The halves are sealed with an O-ring and held together by a spring-loaded clamp with an explosive bolt. The deployed model is 20 in. in diameter, and the center fabric between the domed halves is 38 in. in length. The center section consists of an inside bladder made of 9-oz/yd² urethane-coated nylon fabric. Adjacent to the bladder is a 1/4-in. layer of 6-lb/ft³ closed-cell vinyl foam. Adjacent to the vinyl foam layer is a fiber glass fabric (9-oz/yd²) of sandwich-type construction. The outer covering was 3-mil Mylar® on Models 1 and 2 and 6-mil polyethylene on Models 3 and 4. An adhesive was used to bond the fabrics together and to the epoxy bulkheads.

The fiber glass sandwich section was impregnated with a resin which was activated by a catalyzing vapor (H₂O). Figure 4 shows the catalyst container mounted on top of the domed half of the model. Two solenoid valves are used to control the catalyst flow to the fiber glass fabric sandwich section. A heater was used to maintain the proper catalyst temperature (approximately 80°F).

2.3 TEST CONFIGURATION

The test setup (Figs. 4 and 5) shows the model mounted in a cage in the test chamber. The strain-gage-type load cell which was used to measure the vehicle weight was located at the top of the cage (Fig. 4). This cage was used to support the heat flux lamps (quartz envelope tungsten filament lamps), which were used to maintain the proper temperature on the model surface. The front surfaced mirrors shown in Fig. 5 permitted visual monitoring of the back side of the test model.

2.4 INSTRUMENTATION

Chamber pressure was monitored with an alphasatron and two ionization gages. Copper-constantan thermocouples were used to monitor the LN₂ liner temperature. The power input in the heat flux lamps was measured by standard a-c voltmeters and ammeters. Variable transformers were used to change the output level of the lamps. A total radiation thermopile detector was used to determine the output level from the heat flux lamps. A strain-gage-type load cell was used to monitor the weight of the test model. A 25-channel data logger system and strip chart recorders were used to record all test data. A camera

located outside a chamber port was used to obtain permanent motion-picture coverage of the deployment and rigidization. A closed-circuit television located inside the chamber was used to monitor the deployment of Model 4.

SECTION III PROCEDURE

3.1 PRE-TEST PREPARATION

Reflectance measurements were made on a sample of model surface material over the wavelength range from 0.3 to 7 microns. These measurements were then used in conjunction with the output of the heat flux lamp (0.3 to 7 microns) to determine what output would be required from the lamps to produce the desired temperature on the model surface. The lamps were then spaced around the vehicle surface to give the desired distribution and output. The total radiation detector was used during the test to monitor the lamp outputs, which were used to calculate the model surface temperature.

3.2 PREPARATION OF TEST MODEL

The deployed model before being prepared for the test is shown in Fig. 3. The outer Mylar or polyethylene covering was used to seal the fiber glass section from the water vapor in the atmosphere. That section was purged with dry nitrogen prior to impregnation. A vacuum pump was attached to this section and the section pumped to a low pressure to help impregnate the fiber glass of the model with resin (Fig. 6). After the impregnation was completed, the model was packaged (Fig. 7), sealed with the spring-loaded clamp and explosive bolt, and suspended in the test chamber as shown in Fig. 8.

3.3 TEST PROCEDURE

The ARC (12V) was evacuated to 10^{-5} or 10^{-6} torr, depending on the outgassing load from the test model. After the chamber pressure stabilized, the heat flux lamps were energized, the motion-picture camera was started, and 2 sec later the explosive bolt was fired to initiate deployment (time = 0) of the test model. Figure 9 shows the model partially deployed. Approximately 10 min were allowed for the chamber pressure to recover from the deployment. Then the model was pressurized with CO_2 (2 to 12 torr) to obtain the desired shape. The CO_2 was used instead

of air because it is easily pumped with a 77°K cryopump. The model is shown deployed and properly shaped in Fig. 10. After the model was shaped the flow of the catalyst (H₂O) was started for rigidization. The heat flux lamps maintained the model surface temperature above 65°F during rigidization.

SECTION IV RESULTS AND DISCUSSION

4.1 RESULTS

The test data obtained from these tests consisted of motion pictures of the deployment and rigidization, chamber pressure, model weight loss, and surface temperature. Model 1 was shaped by using atmospheric air, whereas carbon dioxide was used to shape Models 2, 3, and 4.

4.1.1 Model 1

The motion-picture coverage of the first test did not adequately show the top of the model because of insufficient lighting. In this test, the model did not deploy properly. Figure 11 shows the chamber pressure during the test of Model 1. After a chamber pressure of 10^{-5} torr was achieved, the model was deployed. The catalyst was started at 26 min to rigidize the test model. The chamber pressure continued to decrease until the atmospheric air which was used to shape the model was vented into the chamber at 47 min. Thirty minutes pumping time was required for the chamber pressure to recover from this 77°K noncondensable gas load. As a result, the remaining three models were shaped with CO₂.

Figure 12 shows that the model weight had started to decrease prior to deployment. This may have been caused by excess model temperature before deployment. Sixteen minutes prior to deployment, power to lamps was increased to establish a higher curing temperature.

Figure 13 shows the model temperature before and after deployment. The average temperature of a model surface is indicated by the solid lines shown on the temperature curves. The maximum line is the highest temperature located around the centerline of the model, and the minimum line is the temperature on the edge of the fiber glass section which joins the domed halves. The rigidized model is shown in Fig. 14.

4.1.2 Model 2

Additional lighting was added for this test, and the motion-picture coverage was adequate. A chamber pressure of 9×10^{-6} torr was

achieved prior to deployment (Fig. 15). The model was successfully deployed, and the weight decreased as expected (Fig. 16). The leads from the explosive bolts shorted out the heat lamps and the circuitry used to operate the solenoid valves which release the catalyst. This resulted in a delay of approximately 1 hr and the decrease in model temperature shown in Fig. 17. This also resulted in a lower chamber pressure (Fig. 15) since additional time was available to pump prior to introducing the catalyst. The lamps were energized again at 51 min, and the catalyst was started at 55 min and completed at 124 min. Lamp power was reduced at 99 min and turned off at 149 min (Fig. 17). The rigidized model is shown in Fig. 18.

4.1.3 Model 3

Deployment and rigidization were successful, as can be seen in Figs. 9 and 10 taken from the motion pictures. Motion-picture coverage for this test was very good. A chamber pressure of 4×10^{-6} torr (Fig. 19) was attained prior to deployment, and pressures in the low 10^{-5} torr region were maintained during the time the model was being rigidized. The heat lamps were energized 2 min prior to deployment. These points can be seen on Fig. 19 as well as the pressure surges caused by the catalyst. The test model weight loss (Fig. 20) was as expected. The model surface was maintained at a higher temperature (Fig. 21) during this test, and this tended to speed up rigidization. At 74 min, power to the lamps was reduced, resulting in the temperature decrease shown. Figure 22 shows Models 3 and 4 after rigidization.

4.1.4 Model 4

The motion-picture coverage for this test was good, and the deployment and rigidization were successful. The chamber pressure was 10^{-5} torr (Fig. 23) prior to deployment. This was not as low as the pressure attained with Model 3. This was probably because of the excess resin used on this model. Figure 5 shows large amounts of excess resin foam coming from the model. The total weight loss (Fig. 24) was approximately 20 percent more than for Model 3. A stable model surface temperature (Fig. 25) was maintained throughout the rigidization.

4.2 DISCUSSION

4.2.1 Model Deployment

The deployment of Models 2, 3, and 4 was successful. As soon as the explosive bolt was fired to release the spring-loaded clamp, the

model immediately dropped to its fully expanded length. Model 1 did not deploy properly. When the clamp was released, the model did not drop but had to be forced down with air pressure. Indications were that rigidization had started before the model was deployed. This may have been caused by excess heat on the model prior to deployment. In addition, chamber pumping difficulties resulted in a pumpdown time of approximately 3.3 hr, which was 1 hr longer than the pumpdown time required for Models 2, 3, and 4.

4.2.2 Rigidization of Model

Although no structural strength tests were conducted on the models they were checked for rigidization. Each model was well hardened and very rigid.

4.2.3 Model Weight Loss

Model weight should remain constant prior to deployment and drop sharply during deployment. The weight should continue to decrease during rigidization as portions of the catalyst vaporize and the resin outgasses. Models 2, 3, and 4 lost weight as expected. They showed a drop during deployment as the entrapped excess resin and gases were allowed to escape. They continued to lose weight during rigidization as the catalyst was used and the resin cured. Model 1 started to lose weight prior to deployment and did not show a drop during deployment. Indications were that the model temperature prior to deployment was high enough to cause the resin to start to cure before deployment. The weight loss rate during rigidization decreased as the catalyst was used and resin continued to cure.

4.2.4 Chamber Pressure

Chamber pressures maintained throughout the tests were satisfactory considering the large gas loads (mainly H_2O vapor) which had to be removed. Figure 12 shows that approximately 8.5 lb of resin (70-percent butyl acetate and 30-percent dichloroethene) and 8.1 lb of catalyst (H_2O) were added to the test models. Approximately 4.0 lb of the catalyst was used during the 1-hr rigidization time required to cure the resin. Gas loads (H_2O) in the range from 10^2 to 10^4 atm cc/sec were removed (Fig. 2) in order to maintain the chamber pressures shown in Figs. 11, 15, 19, and 23.

4.2.5 Heat Flux System

It was necessary to use the chamber heat flux system to maintain the model surface temperature above 65°F so that the resin would cure and rigidization would occur. The heat flux system is capable of producing a wide range of model surface temperatures. The higher curing temperatures (110 to 120°F) desired to accelerate the curing process were easily attained in those tests.

SECTION V CONCLUSIONS

Deployment and rigidization of Models 2, 3, and 4 in a simulated space environment of 10^{-5} to 10^{-6} torr and 77°K surroundings were successful. Deployment of Model 1 was not as desired, but rigidization was successful.

The heat flux system provided an effective and convenient means to maintain the model surface temperature at a level necessary for the successful curing of the resin.

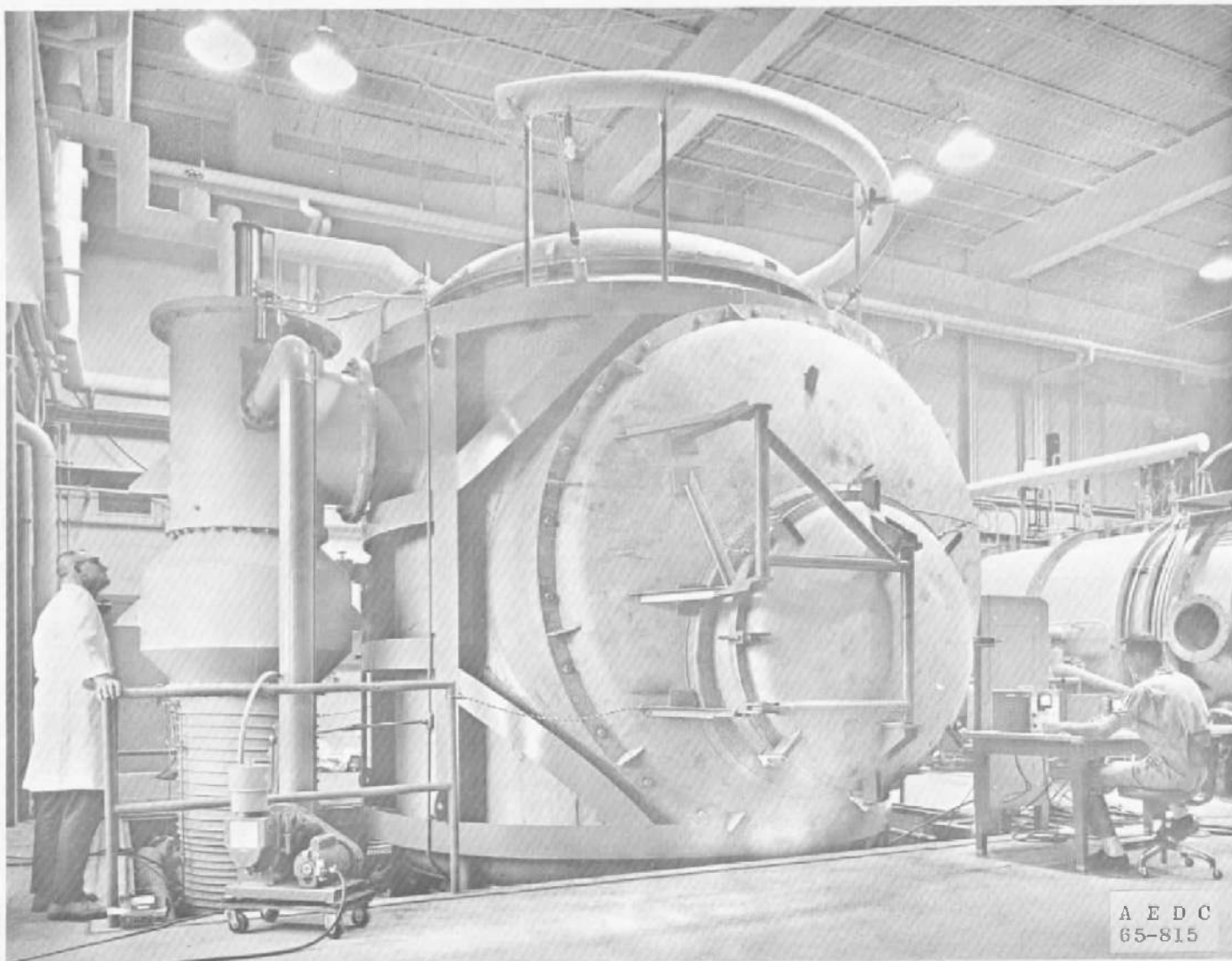


Fig. 1 Aerospace Research Chamber (12V)

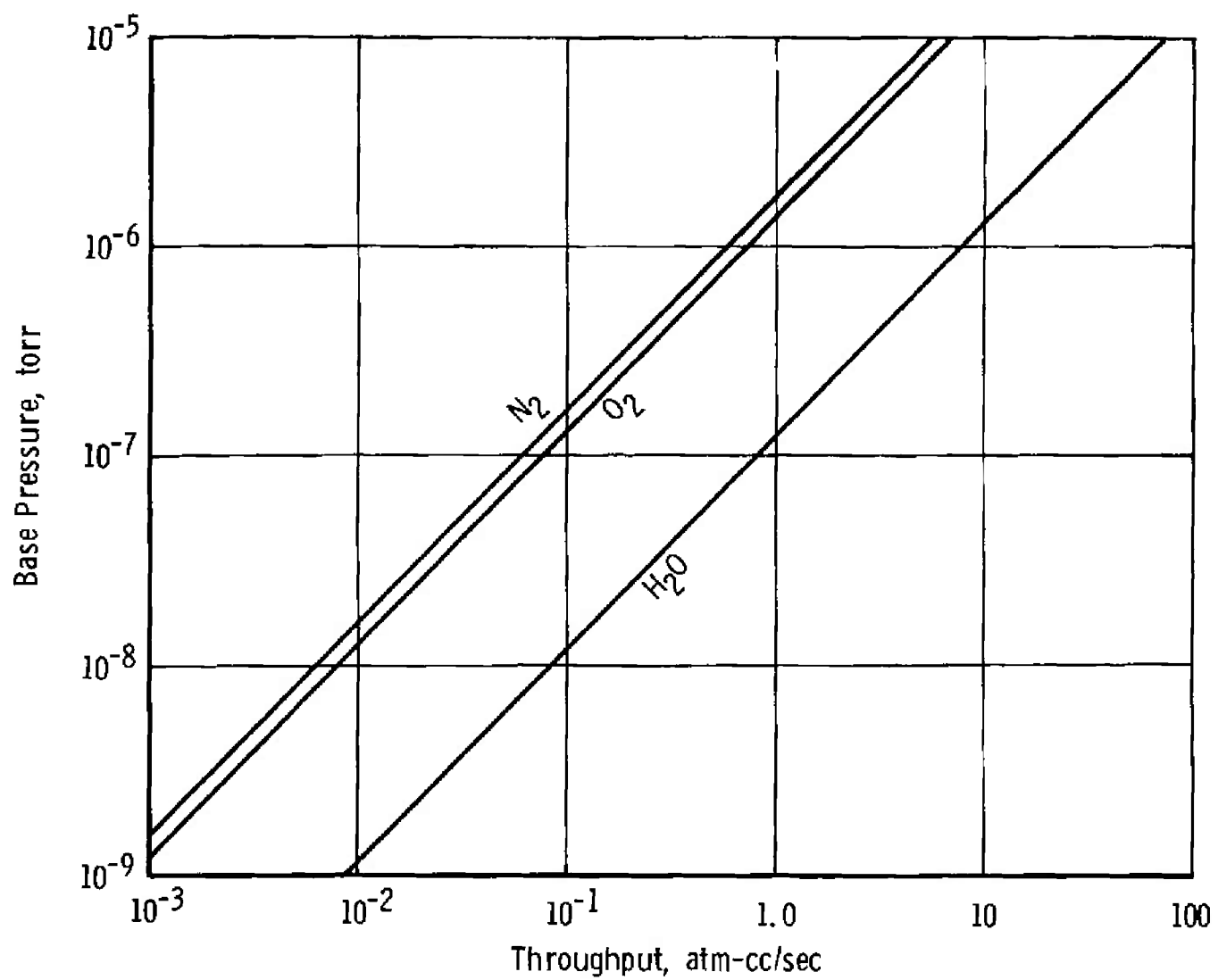


Fig. 2 ARC (12V) Performance

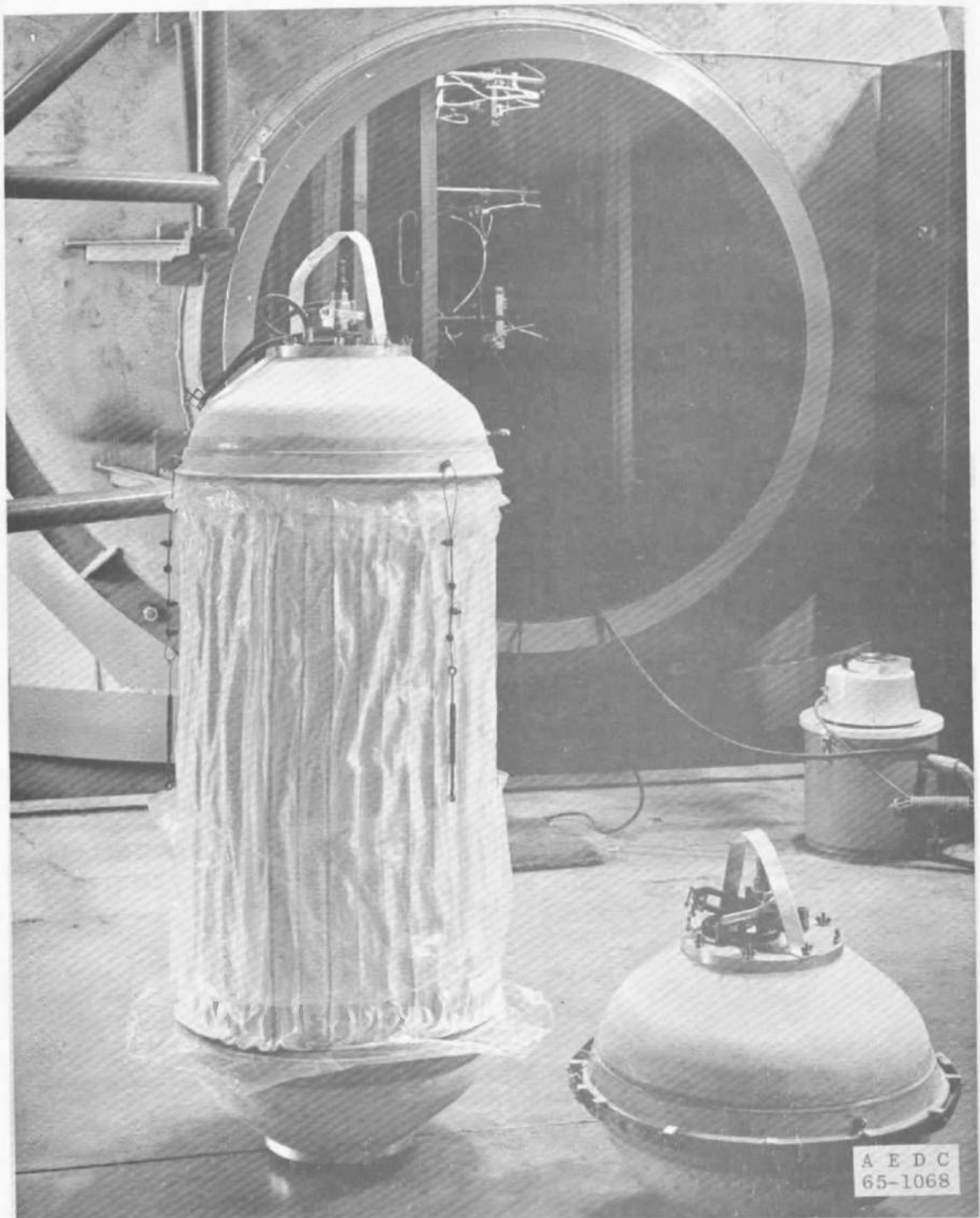


Fig. 3 Packaged and Deployed 1/6-Scale Model, MOL Type

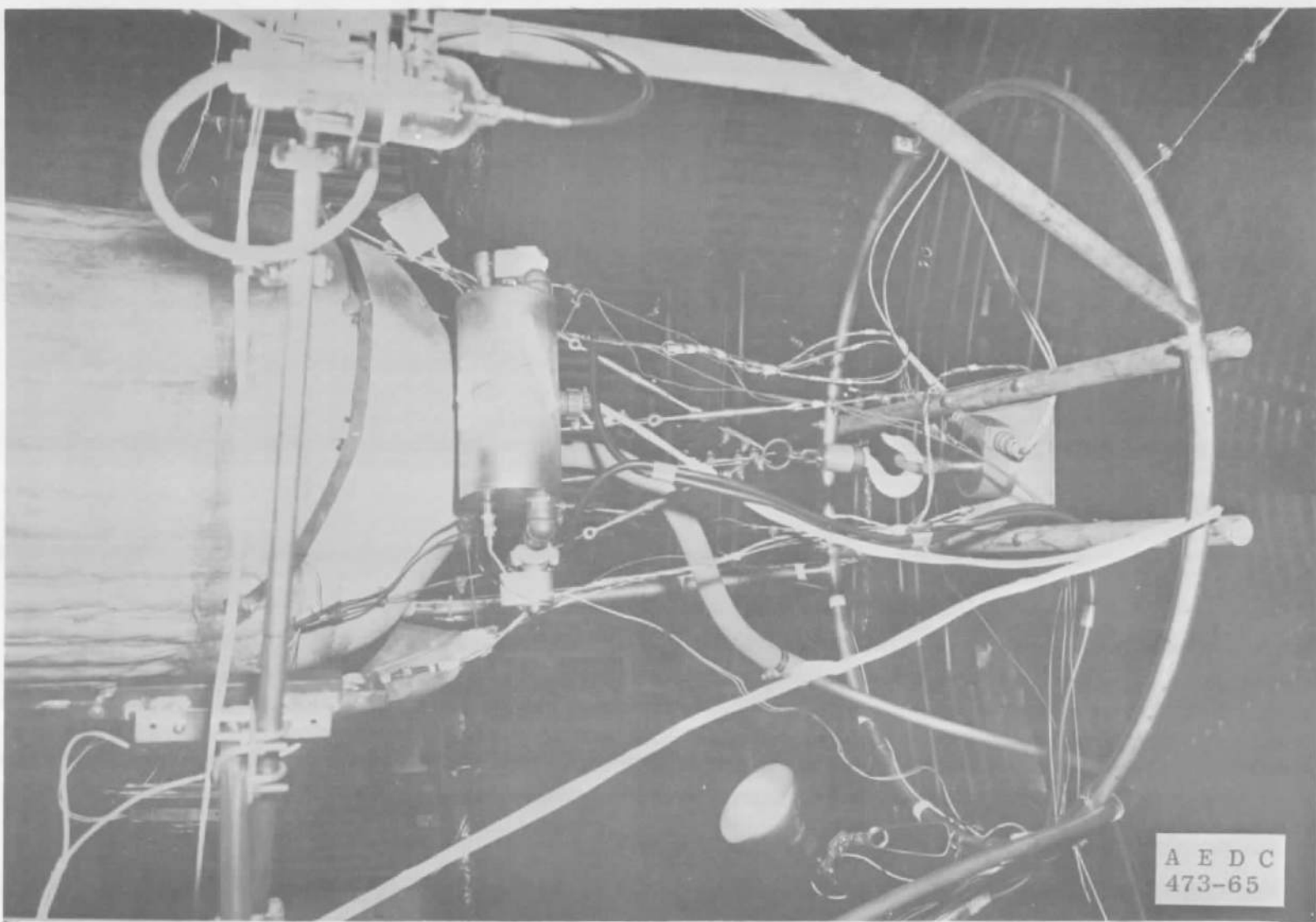


Fig. 4 Model 2 Mounted on Load Cell



Fig. 5 Model 4 Test Configuration



Fig. 6 Model 3 Resin Impregnation

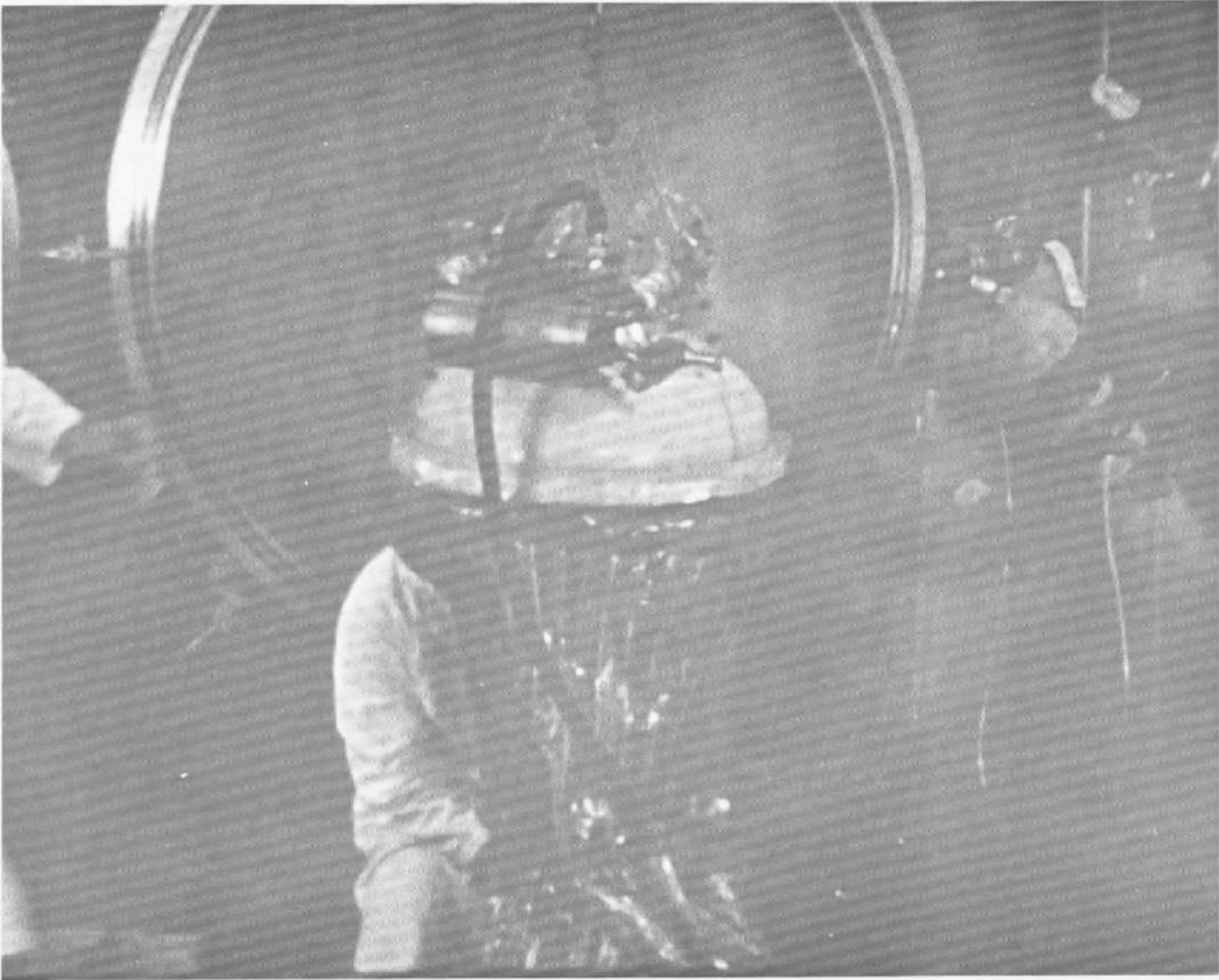


Fig. 7 Packaging Model after Impregnation

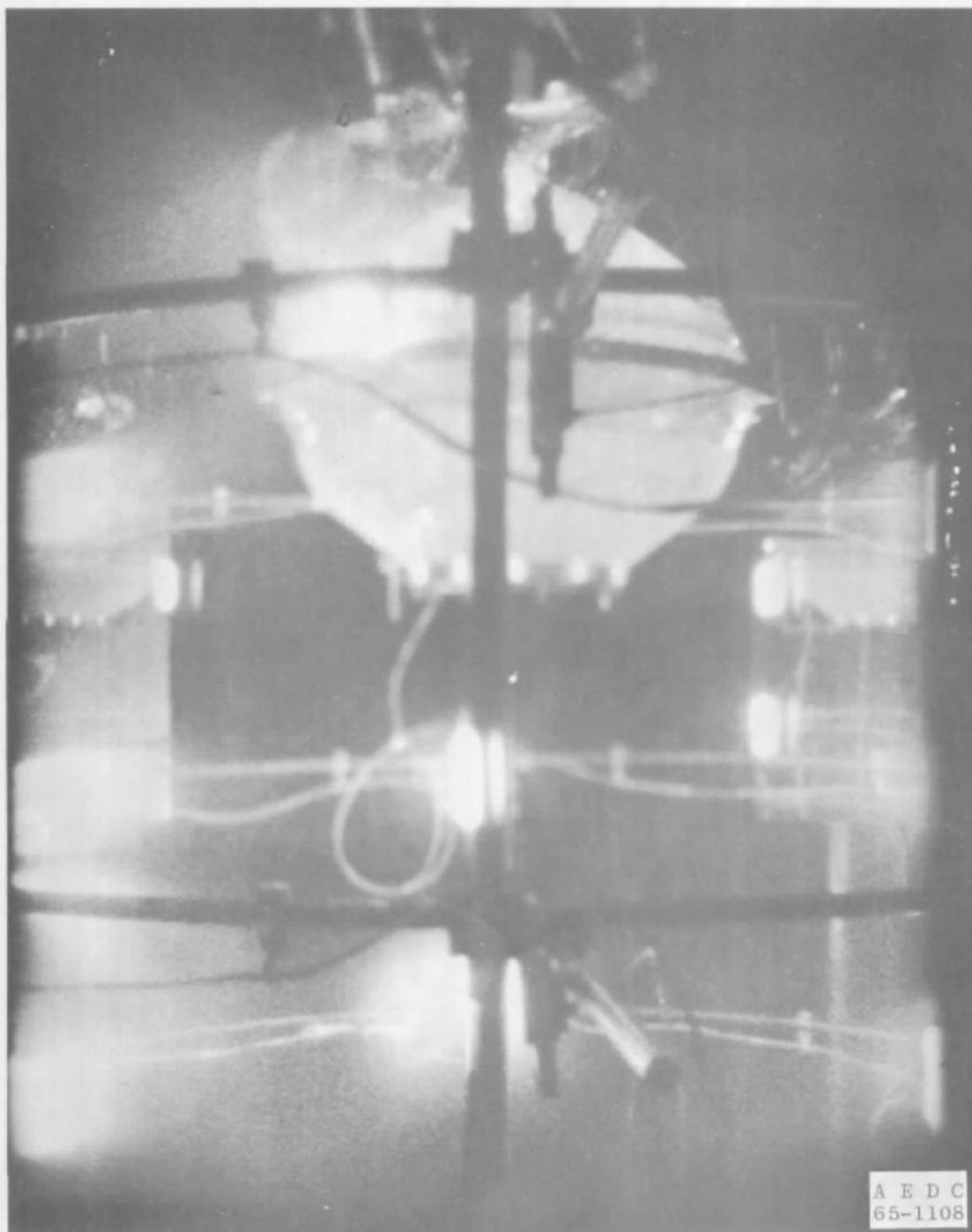


Fig. 8 Packaged Model in Test Chamber



Fig. 9 Model 3 Partially Deployed



Fig. 10 Model 3 Completely Deployed

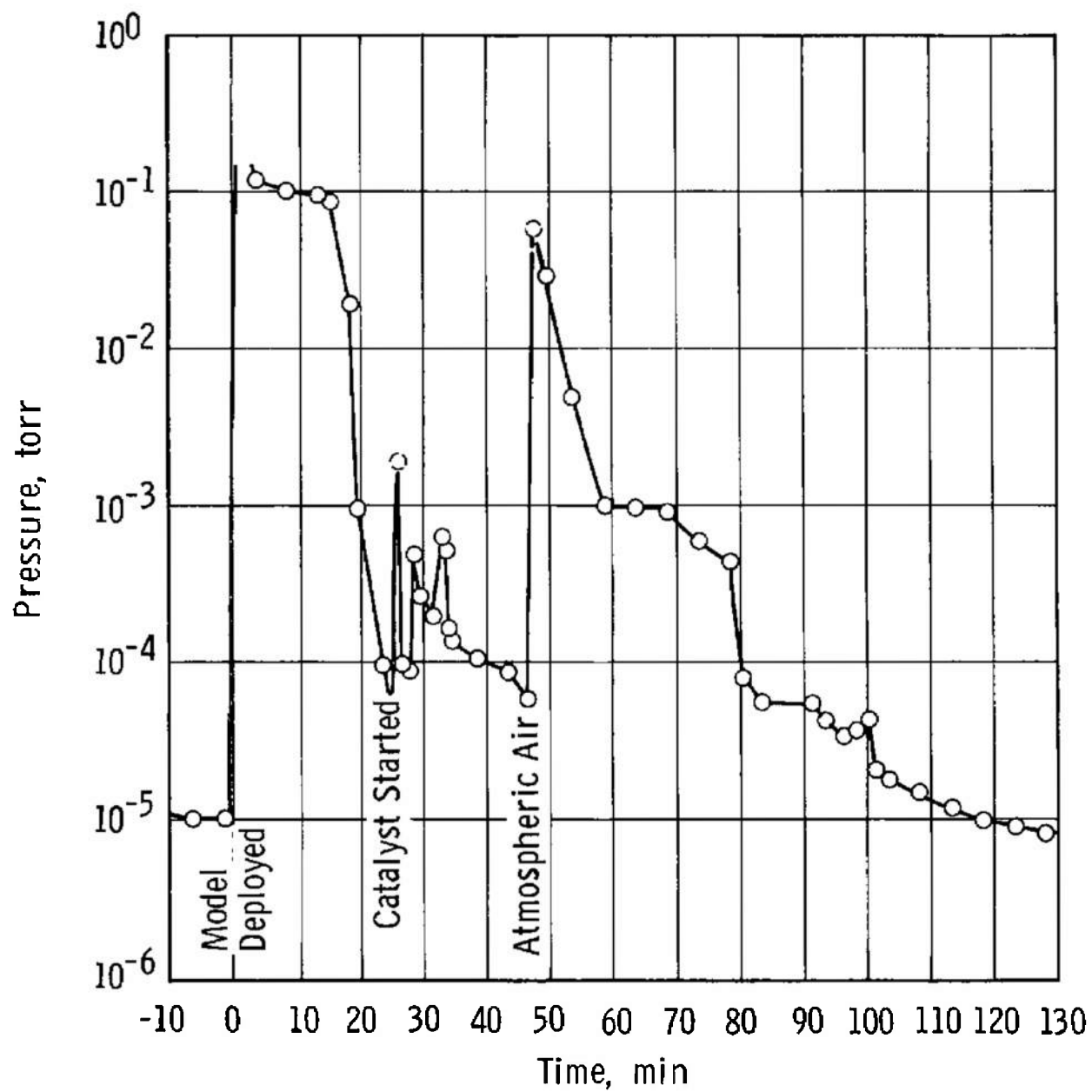


Fig. 11 Model 1 Chamber Pressure

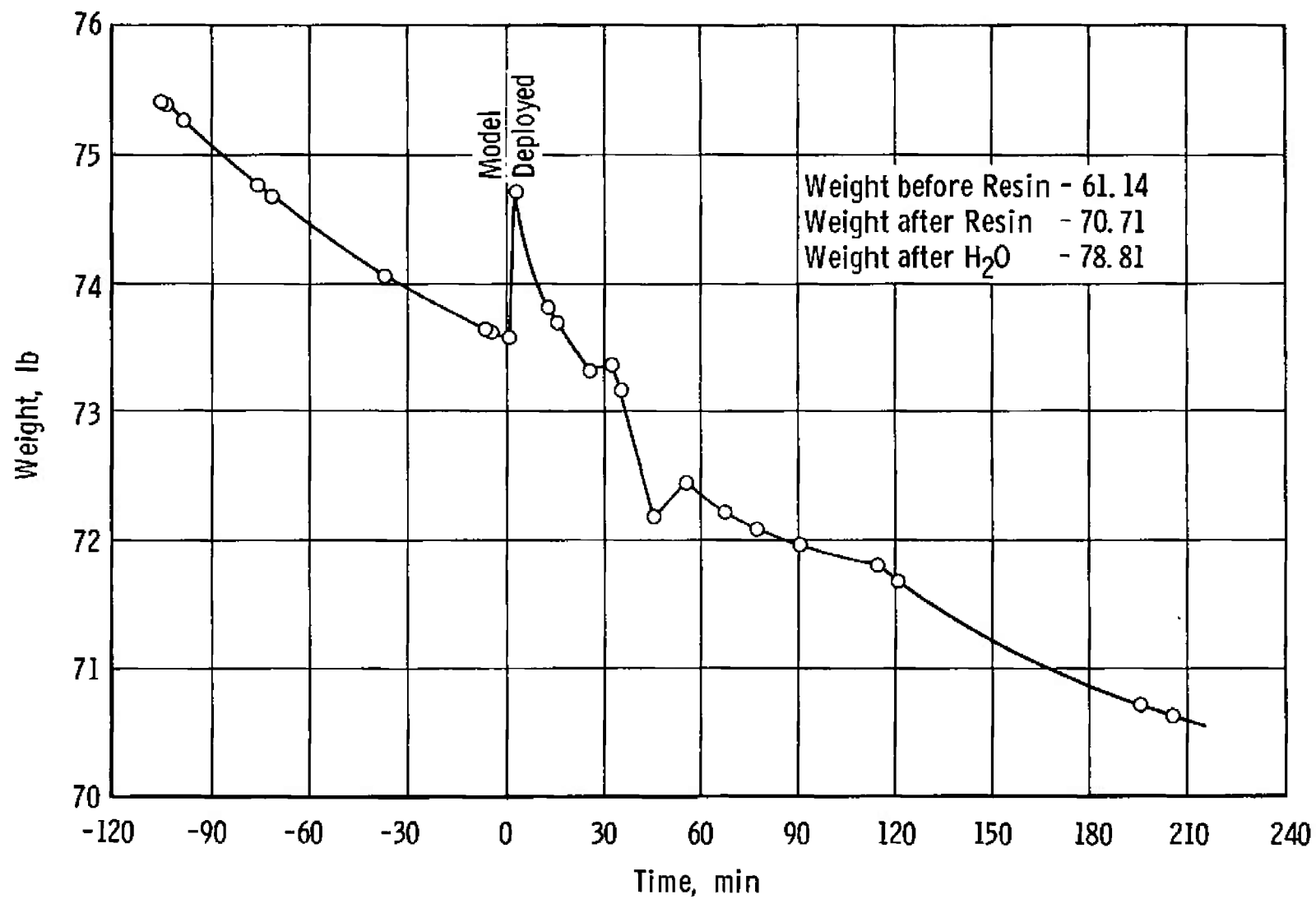


Fig. 12 Model 1 Weight Loss

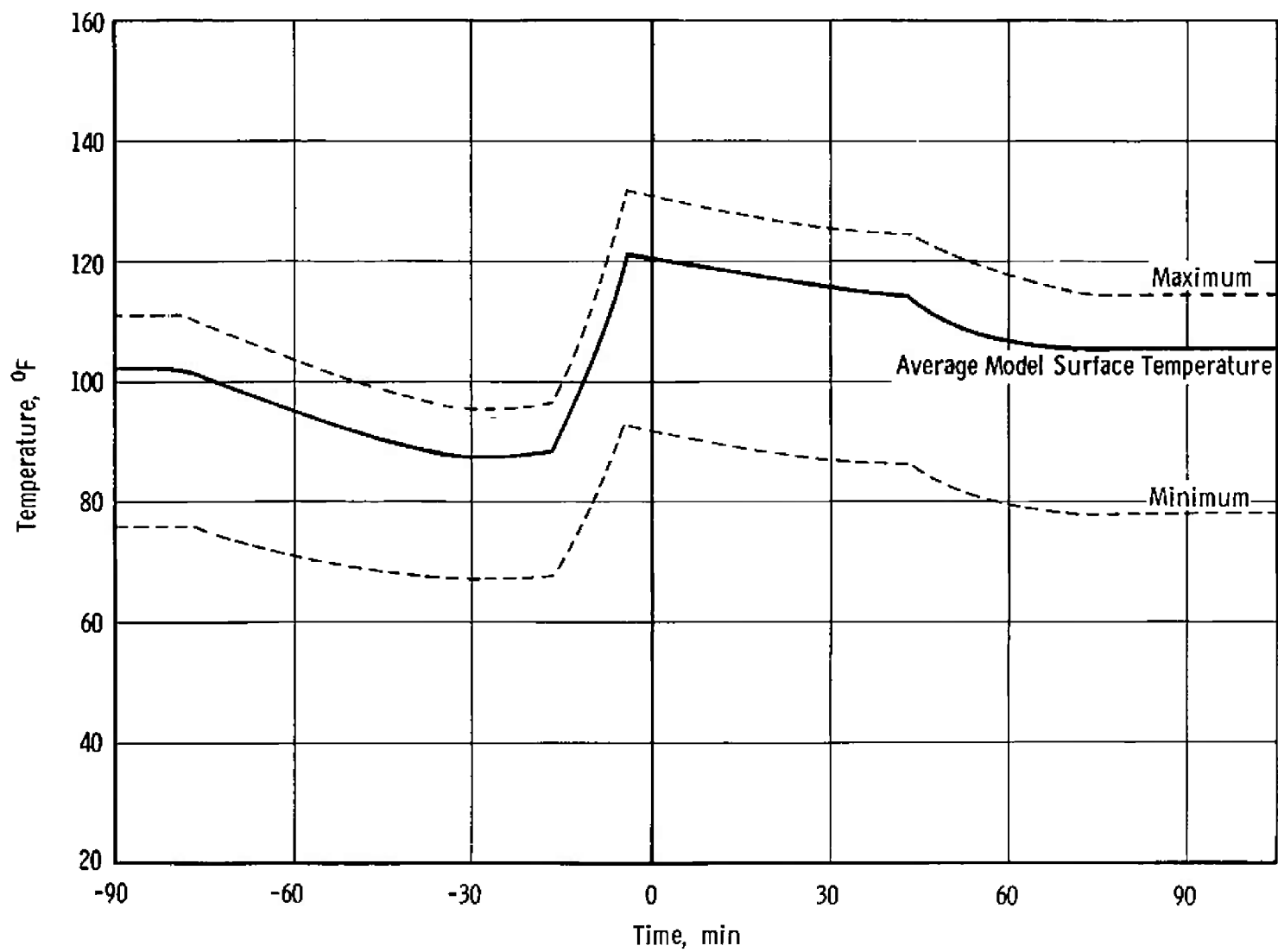


Fig. 13 Model 1 Temperature



Fig. 14 Model 1 after Rigidization

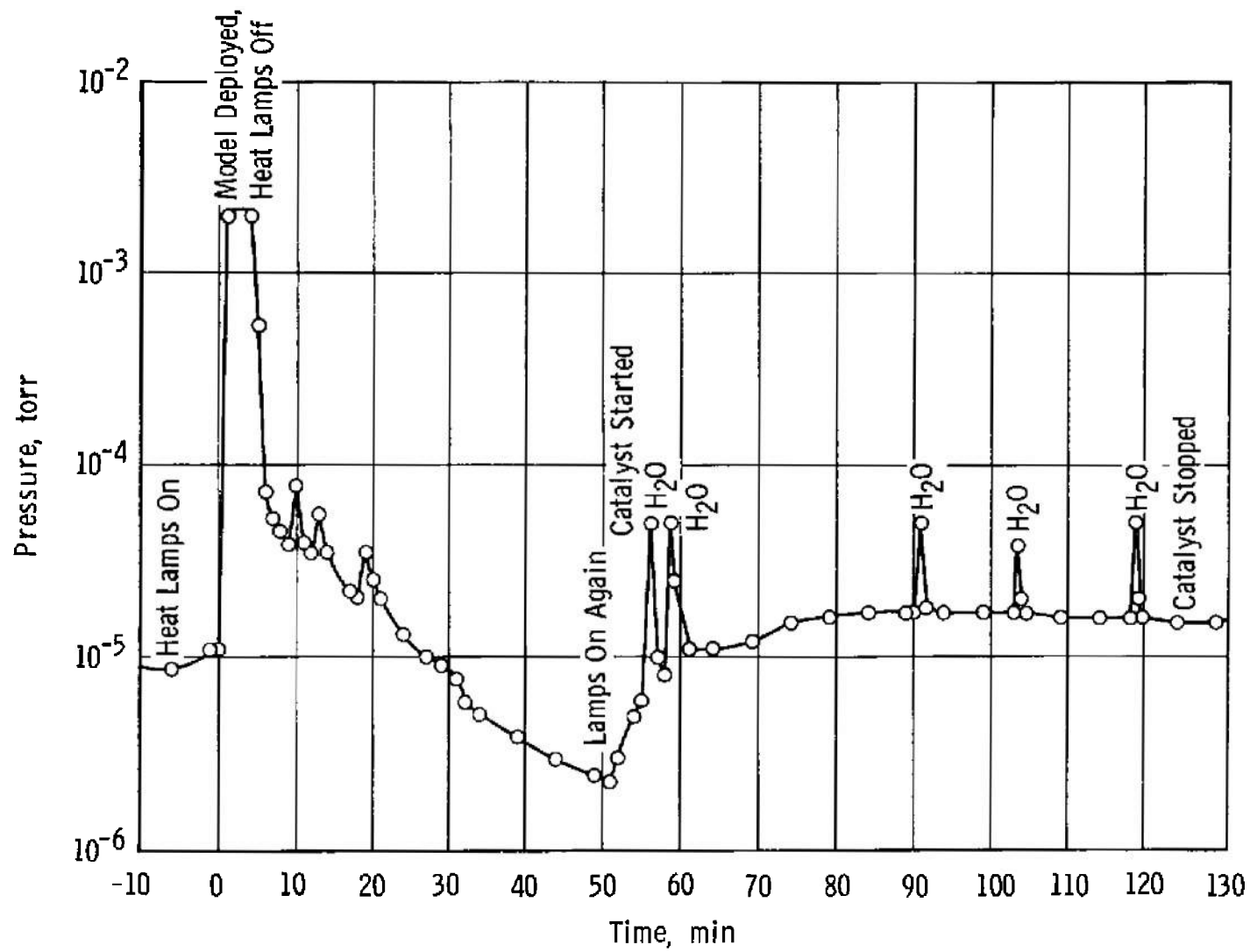


Fig. 15 Model 2 Chamber Pressure

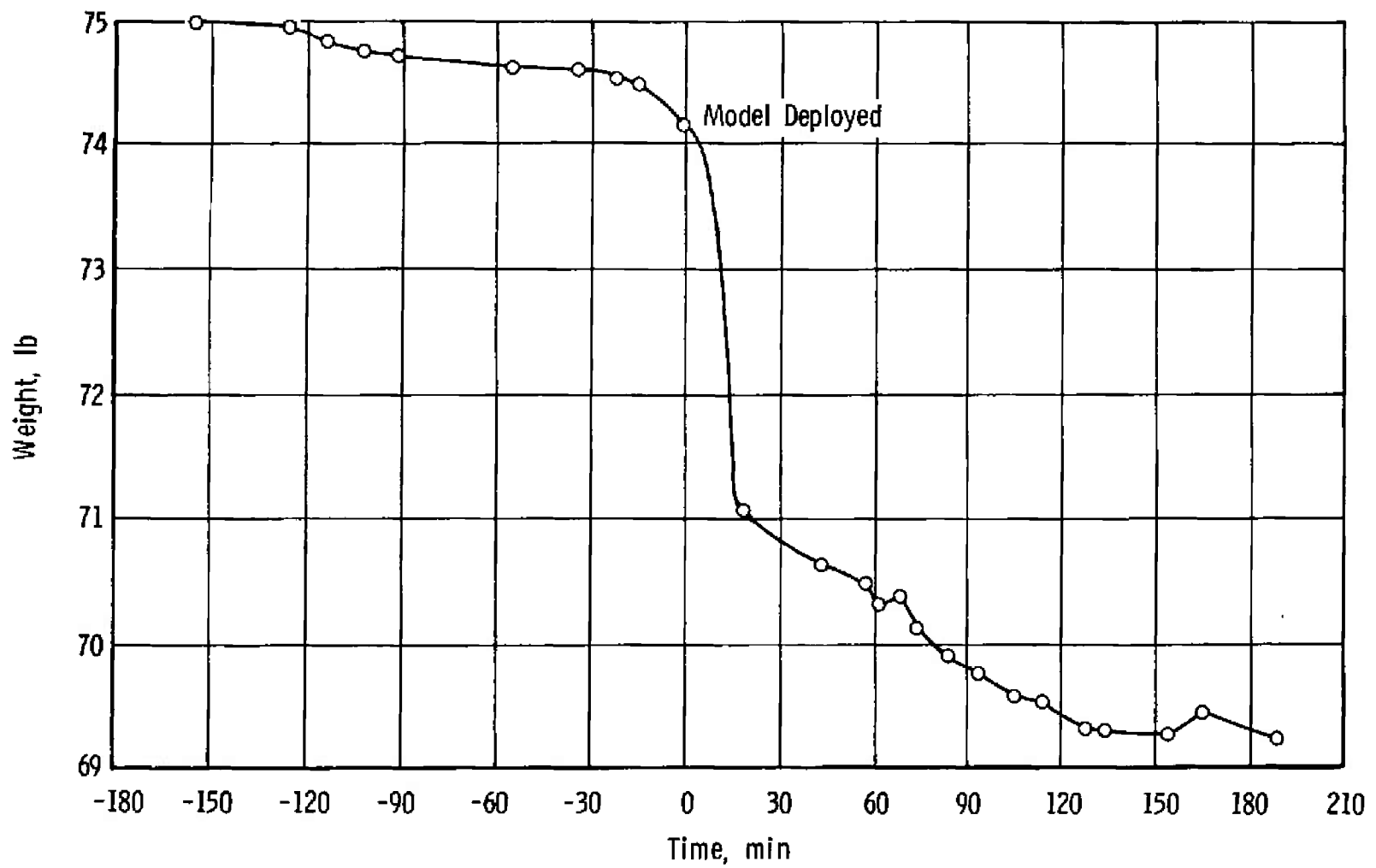


Fig. 16 Model 2 Weight Loss

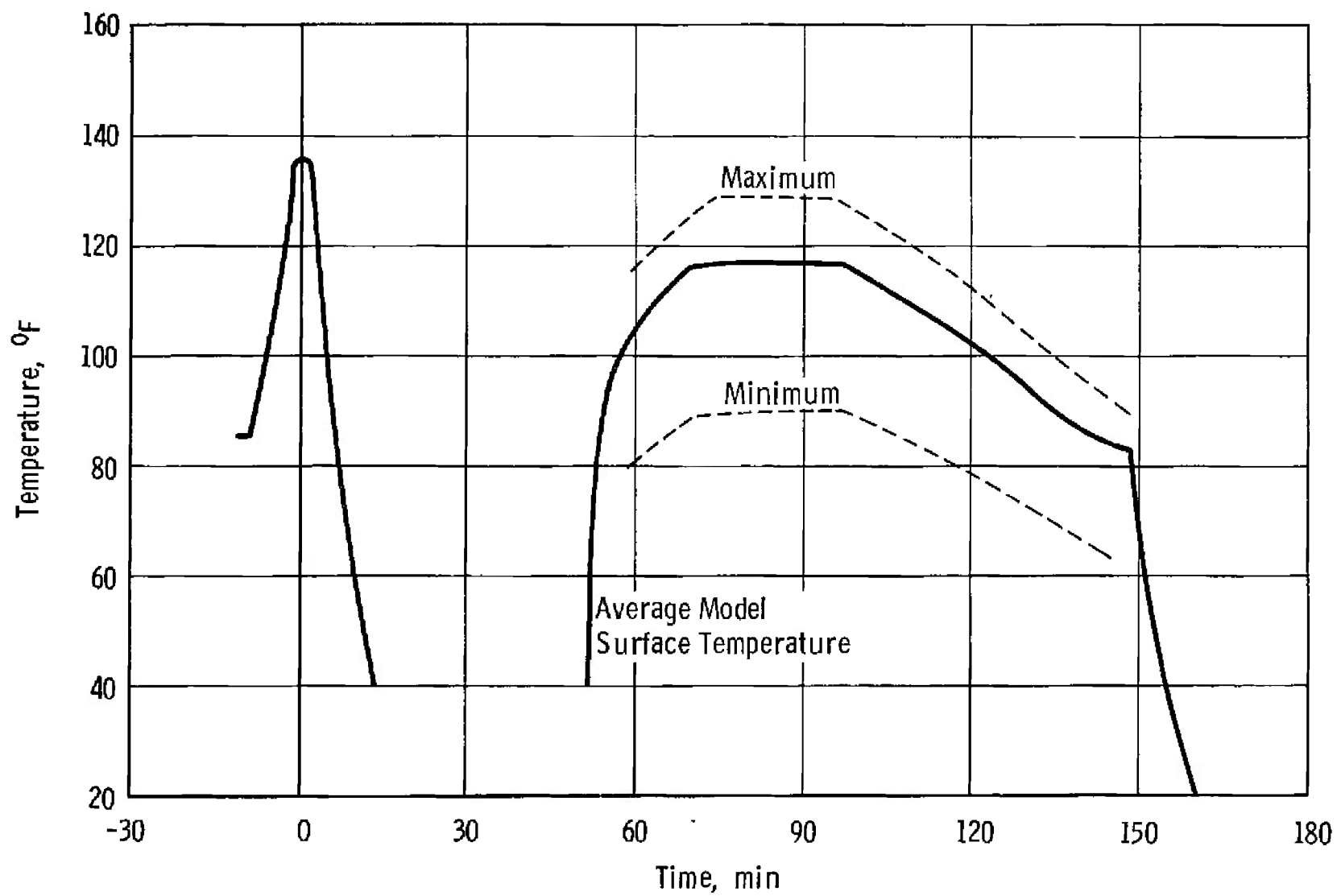


Fig. 17 Model 2 Temperature



Fig. 18 Model 2 after Rigidization

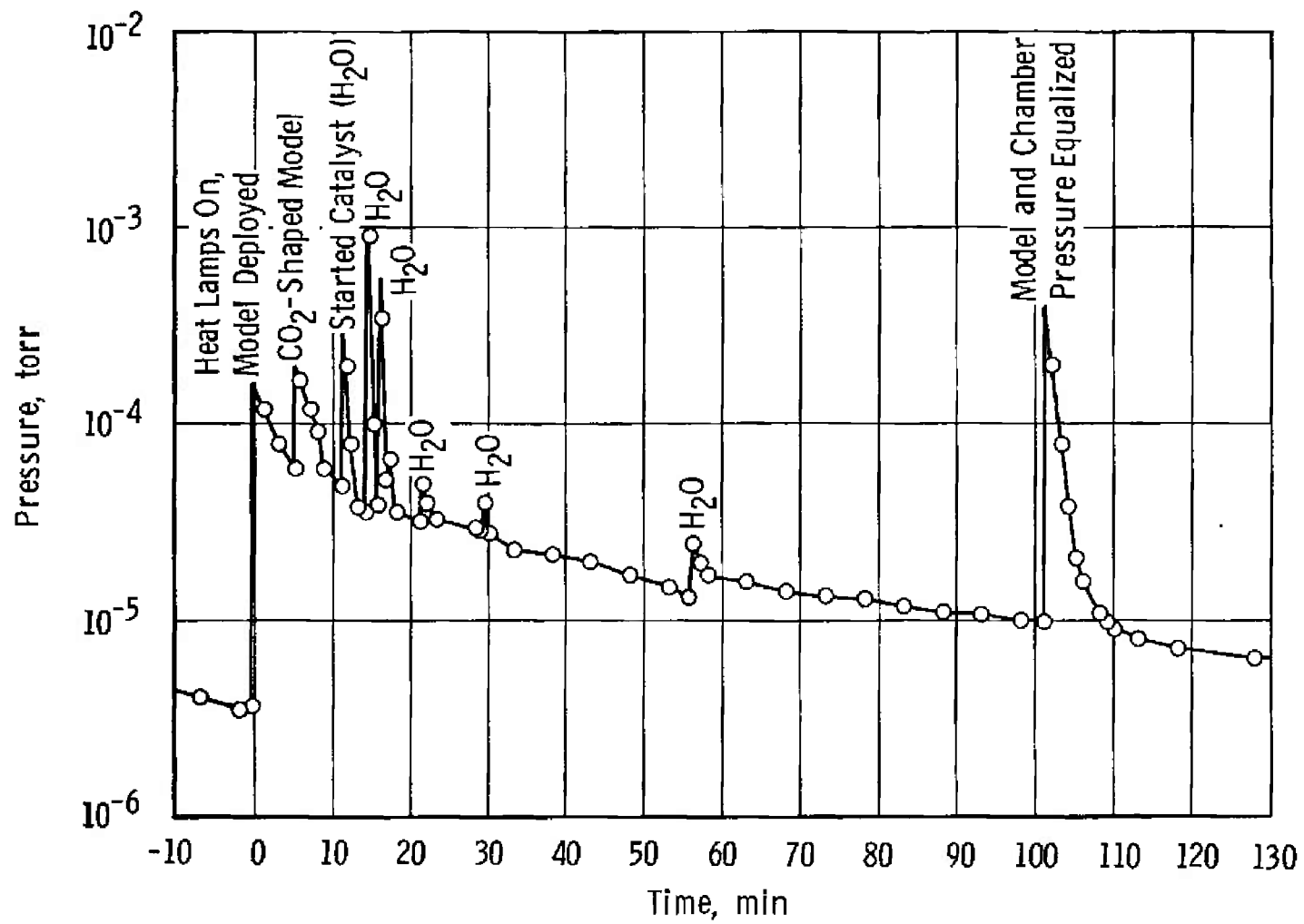


Fig. 19 Model 3 Chamber Pressure

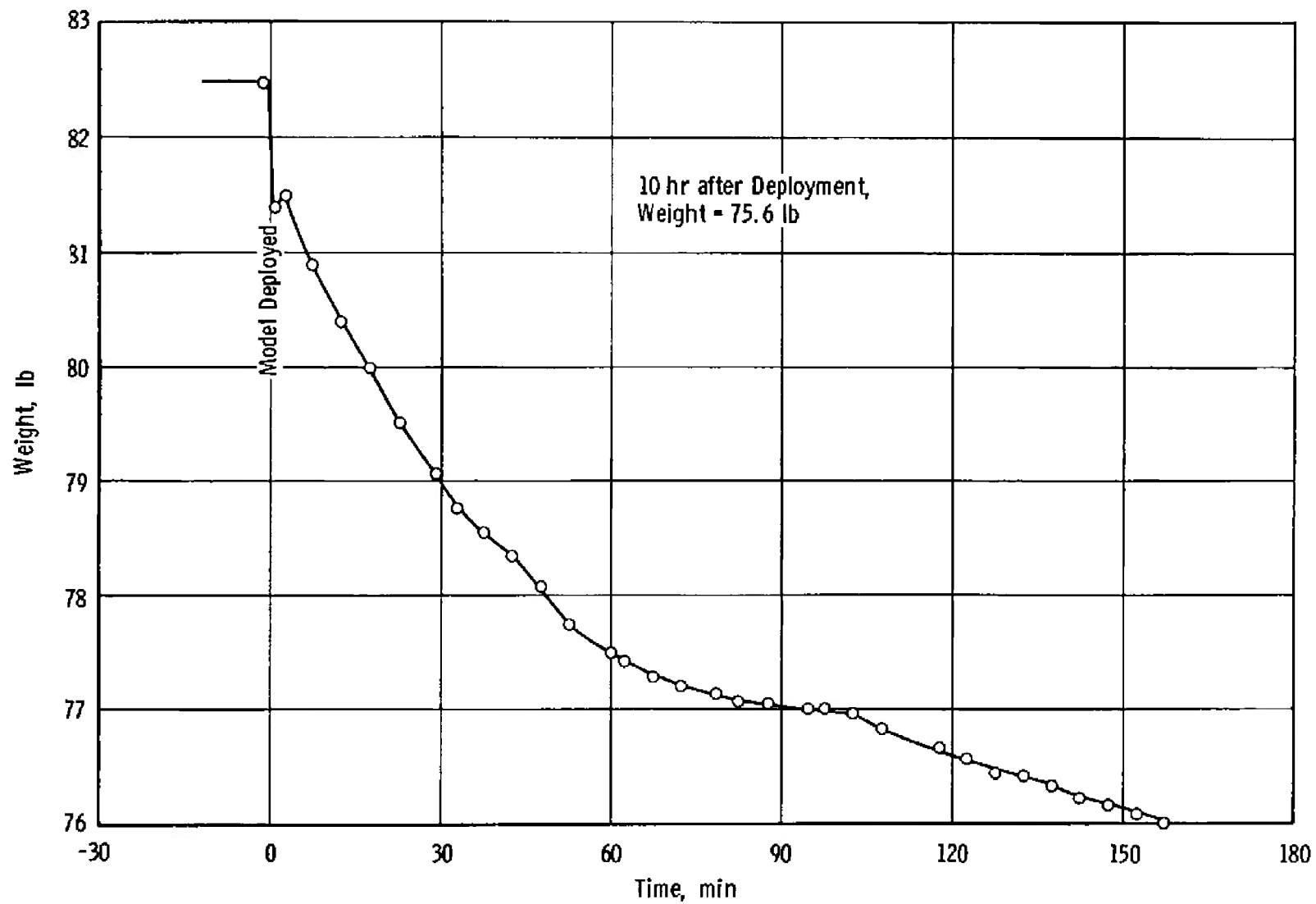


Fig. 20 Model 3 Weight Loss

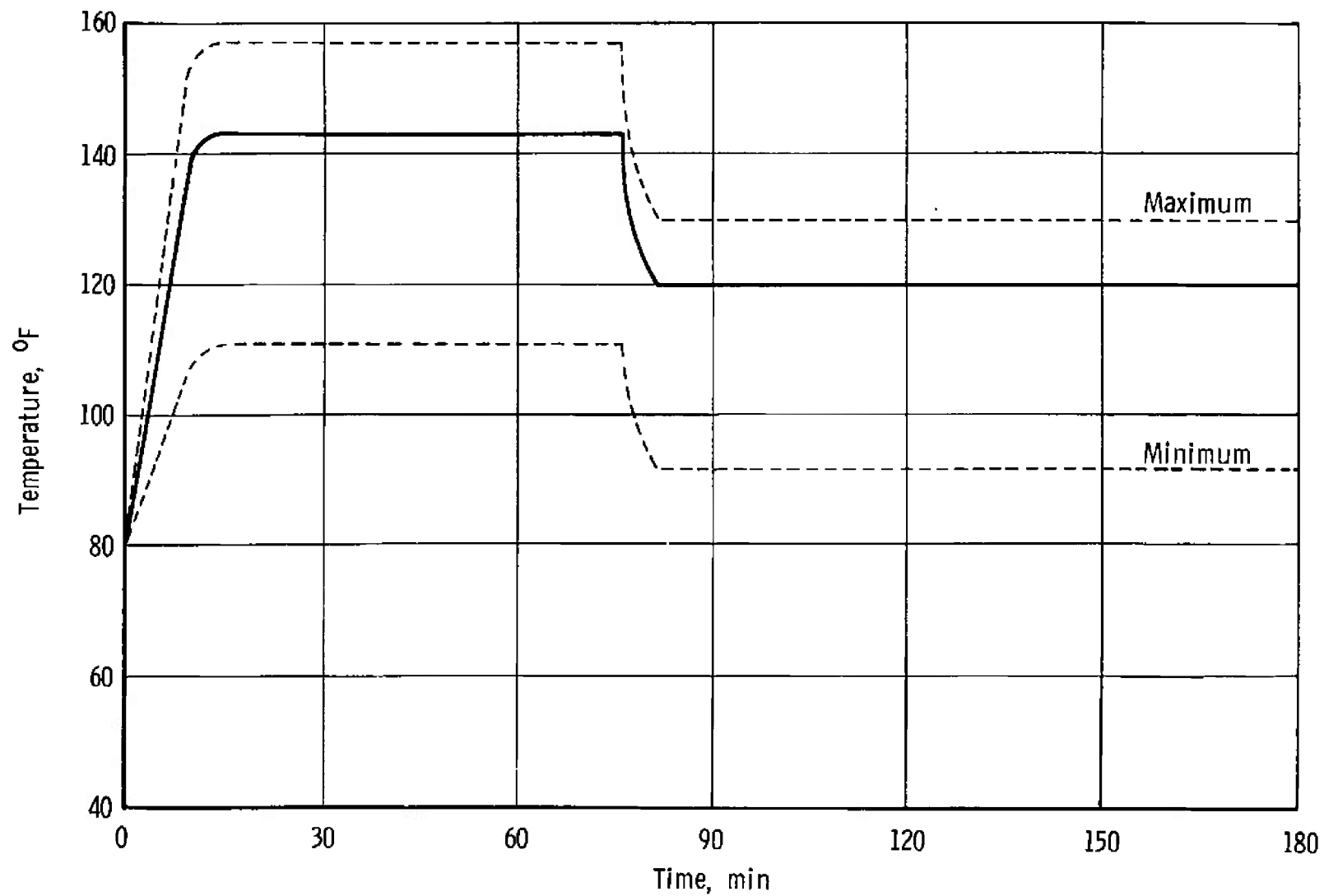


Fig. 21 Model 3 Temperature



Fig. 22 Models 3 and 4 after Rigidization

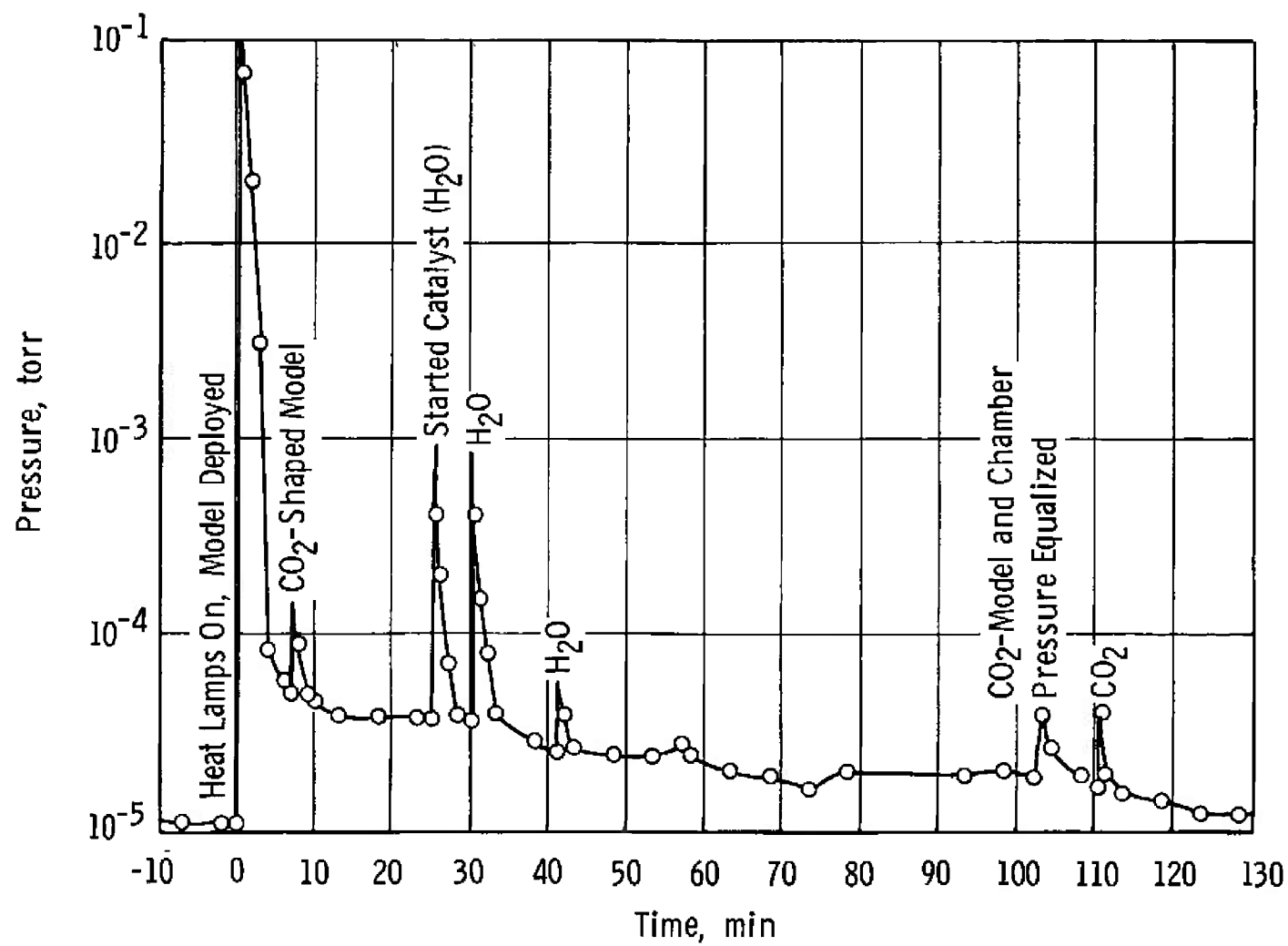


Fig. 23 Model 4 Chamber Pressure

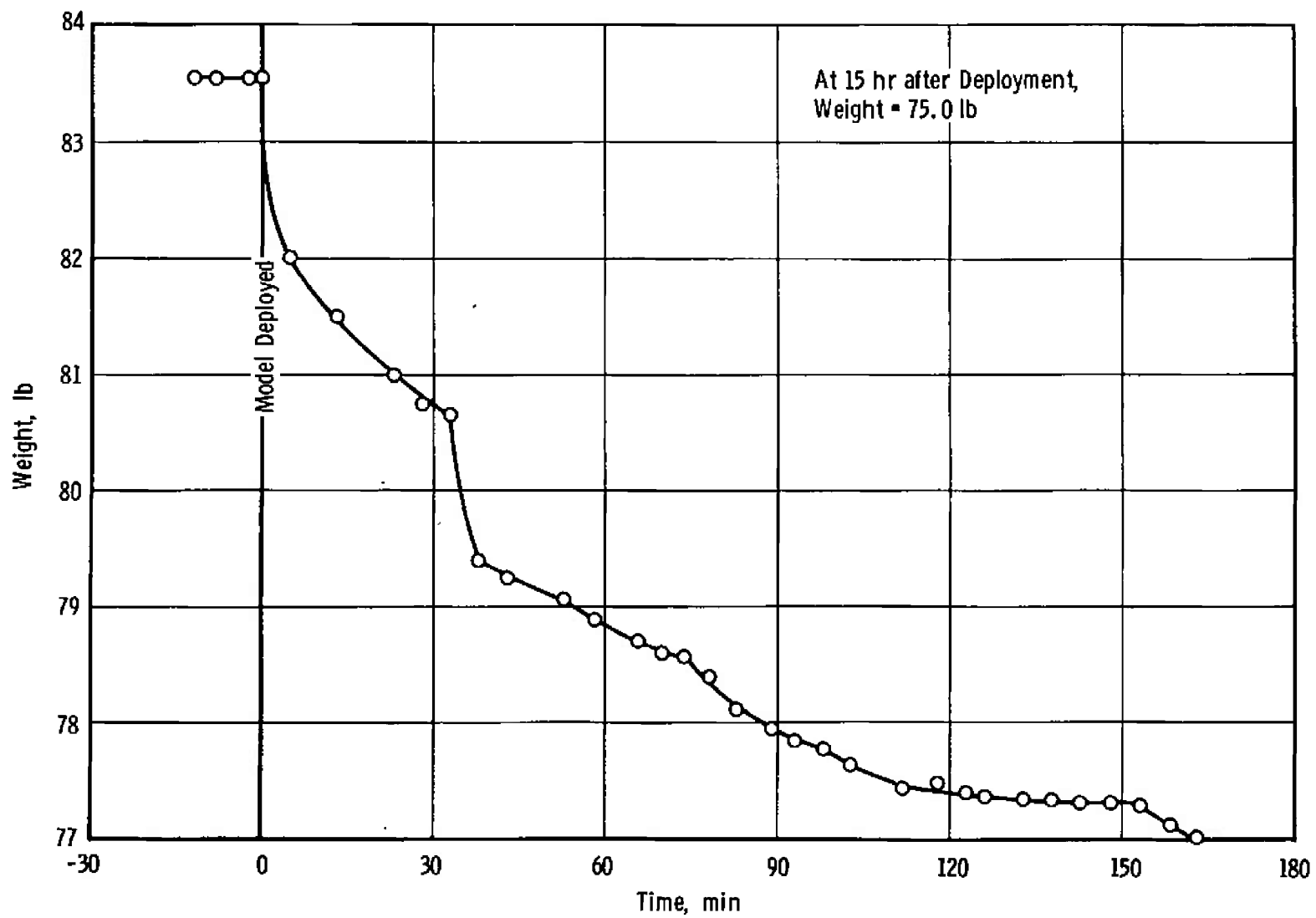


Fig. 24 Model 4 Weight Loss

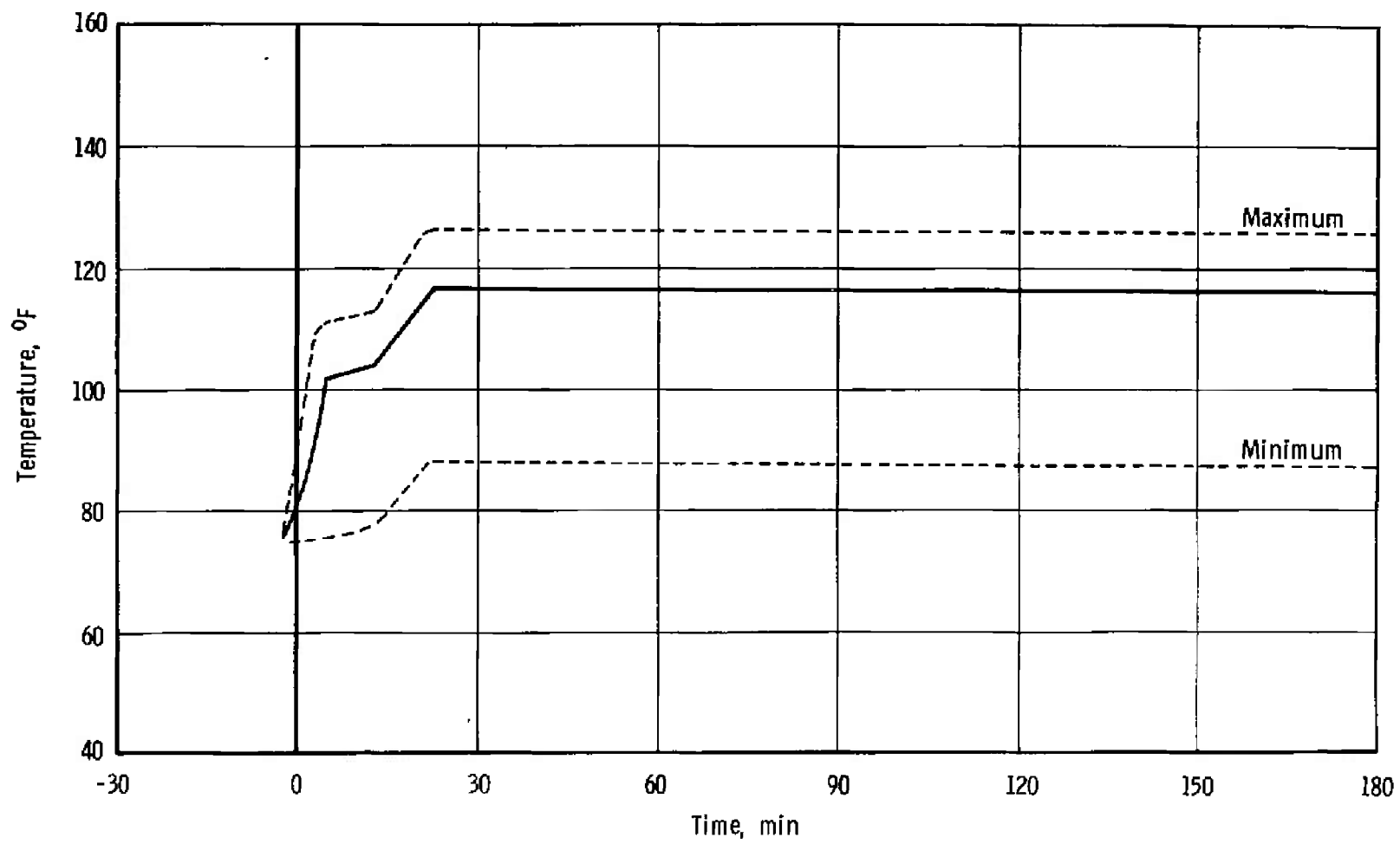


Fig. 25 Model 4 Temperature

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) Arnold Engineering Development Center, ARO, Inc., Operating Contractor, Arnold Air Force Station, Tennessee		2a REPORT SECURITY CLASSIFICATION UNCLASSIFIED
		2b GROUP N/A
3 REPORT TITLE VACUUM TESTING OF EXPANDABLE SELF-RIGIDIZING STRUCTURES		
4 DESCRIPTIVE NOTES (Type of report and inclusive dates) N/A		
5 AUTHOR(S) (Last name, first name, initial) Latture, N. C., ARO, Inc.		
6 REPORT DATE December 1965	7a TOTAL NO OF PAGES 39	7b NO OF REFS 1
8a CONTRACT OR GRANT NO. AF40(600)-1200	9a ORIGINATOR'S REPORT NUMBER(S) AEDC-TR-65-264	
b PROJECT NO 8170		
c Program Element 62405214	9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report) N/A	
d		
10 AVAILABILITY/LIMITATION NOTICES Qualified requesters may obtain copies of this report from DDC. Release to foreign governments or foreign nationals must have prior approval of AEDC.		
11 SUPPLEMENTARY NOTES N/A	12 SPONSORING MILITARY ACTIVITY Aero-Propulsion Laboratory, Air Force Systems Command, Wright- Patterson Air Force Base, Ohio	
13 ABSTRACT Four expandable, self-rigidizing structures were impregnated with a water setting resin and packaged for deployment in a vacuum of 10^{-5} torr while exposed to 77°K cold walls in a space environmental chamber. The high pumping speeds available with this chamber permitted the removal of the large gas loads from the structure while maintaining test pressures of 10^{-5} torr. Water was used as a catalyst, and infrared heat lamps were used to maintain temperature control of the structures. Deployment was completely successful on three structures and partially successful on one. Rigidization of all four structures was successful.		

KEY WORDS

LINK A

LINK B

LINK C

ROLE

WT

ROLE

WT

ROLE

WT

Manned Orbiting Laboratory structures

MOL

self-rigidizing structures

expandable structures

1/6-scale models

performance

resin impregnation

INSTRUCTIONS

1. **ORIGINATING ACTIVITY:** Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (corporate author) issuing the report.

2a. **REPORT SECURITY CLASSIFICATION:** Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. **GROUP:** Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. **REPORT TITLE:** Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. **DESCRIPTIVE NOTES:** If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. **AUTHOR(S):** Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. **REPORT DATE:** Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7a. **TOTAL NUMBER OF PAGES:** The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. **NUMBER OF REFERENCES:** Enter the total number of references cited in the report.

8a. **CONTRACT OR GRANT NUMBER:** If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. **PROJECT NUMBER:** Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. **ORIGINATOR'S REPORT NUMBER(S):** Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. **OTHER REPORT NUMBER(S):** If the report has been assigned any other report numbers (either by the originator or by the sponsor), also enter this number(s).

10. **AVAILABILITY/LIMITATION NOTICES:** Enter any limitations on further dissemination of the report, other than those

imposed by security classification, using standard statements such as:

- (1) "Qualified requesters may obtain copies of this report from DDC."
- (2) "Foreign announcement and dissemination of this report by DDC is not authorized."
- (3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through _____."
- (4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through _____."
- (5) "All distribution of this report is controlled. Qualified DDC users shall request through _____."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. **SUPPLEMENTARY NOTES:** Use for additional explanatory notes.

12. **SPONSORING MILITARY ACTIVITY:** Enter the name of the departmental project office or laboratory sponsoring (paying for) the research and development. Include address.

13. **ABSTRACT:** Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as (TS), (S), (C), or (U).

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. **KEY WORDS:** Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.