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Final Report

Project 297

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Development and Test of a Two-Man Hot Air Balloon System

RAVEN
industries, inc.
Sioux Falls, South Dakota

CONFIDENTIAL

Final Report

Project 297

Development and Test of a Two-Man Hot Air Balloon System

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20 November 1963

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I. INTRODUCTION

In 1962, Raven Industries, Inc. completed a program, under contract with the Office of Naval Research, to develop a hot air balloon system suitable for sustained flight with one man. The accomplishments of that program were presented in Raven Industries Report 1863. Satisfactory results were obtained and a one man system was successfully developed and repeatedly flown.

At the end of that program a second project was undertaken to design and fabricate a two-man hot air balloon system, capable of carrying a 560 pound payload with a five to six hour fuel supply. Developmental objectives included the following:

(1) To provide a simple inflation device of minimum weight and size.
(2) To employ a launching technique which will permit unskilled personnel to inflate the balloon under adverse conditions from an unprepared launch area.
(3) To provide a compact unit capable of being transported to a remote launching site without a vehicle.
(4) To provide a balloon envelope so constructed from lightweight, non-porous fabric as to be able to withstand rough usage.
(5) To provide a simple flight profile control mechanism which unskilled persons can learn to operate quickly.

At the end of the program period (1 September 1963), it was expected that a working system would have been built and tested and that a description of the system and its use would be prepared. As part of the program, a brief training syllabus was to be supplied for use in developing a program for educating potential crew members.

This Final Report will present the results of the project (Project 297). In general, the program was successful and a workable system has been developed. All of the objectives (1) through (4) were met. Although a control mechanism was considered, and some components procured, it was not fabricated and tested.

The physical items produced under this program include three balloons and two sets each of gondolas, burners, tanks and instruments. The full list is presented as Appendix I. Appendix II is a check list and guide for operating the two man system. Appendix III is the training syllabus and Appendix IV contains full drawings of the components of the balloon system.

In the next section of the report the work which has led to this position will be described.

II. PROJECT REVIEW

When this project was begun, a one-man hot-air balloon system existed in which lift was derived from a propane burner and fuel supply (up to three hours) carried on board. The balloon was made from a laminate of nylon flare cloth weighing 1.1 oz. per square yard and .35 mil Mylar film. Initial ground inflation was accomplished with a remote heater, using a blower to bring hot air into the balloon.

In order to meet the project objectives, most of the one man system components had to be changed. These changes included:

- Design of a larger balloon
- Development of a larger fuel supply and burner system
- Reduction in system weight, to improve transportability
- Development of a two man gondola

All of the above requirements were met, and the results demonstrated in various field flight tests. Although a number of studies and design efforts were concurrent, it is convenient to describe various system changes in terms of the chronology of flight tests.

The first element of the two man system to be designed was the balloon itself. The laminated Mylar-nylon material developed for the one man system was used, as was the general gore profile. The size was increased to a diameter of 50 feet, and a volume of 60,930 cubic feet. Following preliminary ground checks in Sioux Falls, a full scale flight was made on 21 September 1962, at Las Vegas, Nevada. Two existing burners were used to provide adequate in-flight heating and a three hour flight was made with the following weight schedule:

Balloon	110 lbs.
Controls, tanks & fuel	220
Gondola and rigging	90
Two men	410
Total	830 lbs.

The remote heater and blower system developed for the one man unit was used, and a two man gondola was constructed from a square of plywood with webbing straps to connect to the balloon base. A Poeschel ring was used to hold open a skirt, extending below the balloon base. The in-flight burners were mounted on a load bar inside this skirt. Figures 1 - 3 show this balloon, the CA-50, during inflation and flight at Las Vegas. The flight went entirely according to schedule, including the rapid deflation accomplished by opening a cylindrical section in the crown of the balloon. This opening was effected by firing an electric squib with two flashlight cells.

This flight on 21 September demonstrated that a two man hot air balloon system was indeed feasible. Operations were conducted from an unprepared site, with all the necessary ground support equipment brought from Sioux Falls, South Dakota, by car and trailer.

Despite an ambient temperature of 90 to 95°F on the ground, the balloon performed well, without overheating the skin. Even when flown up to

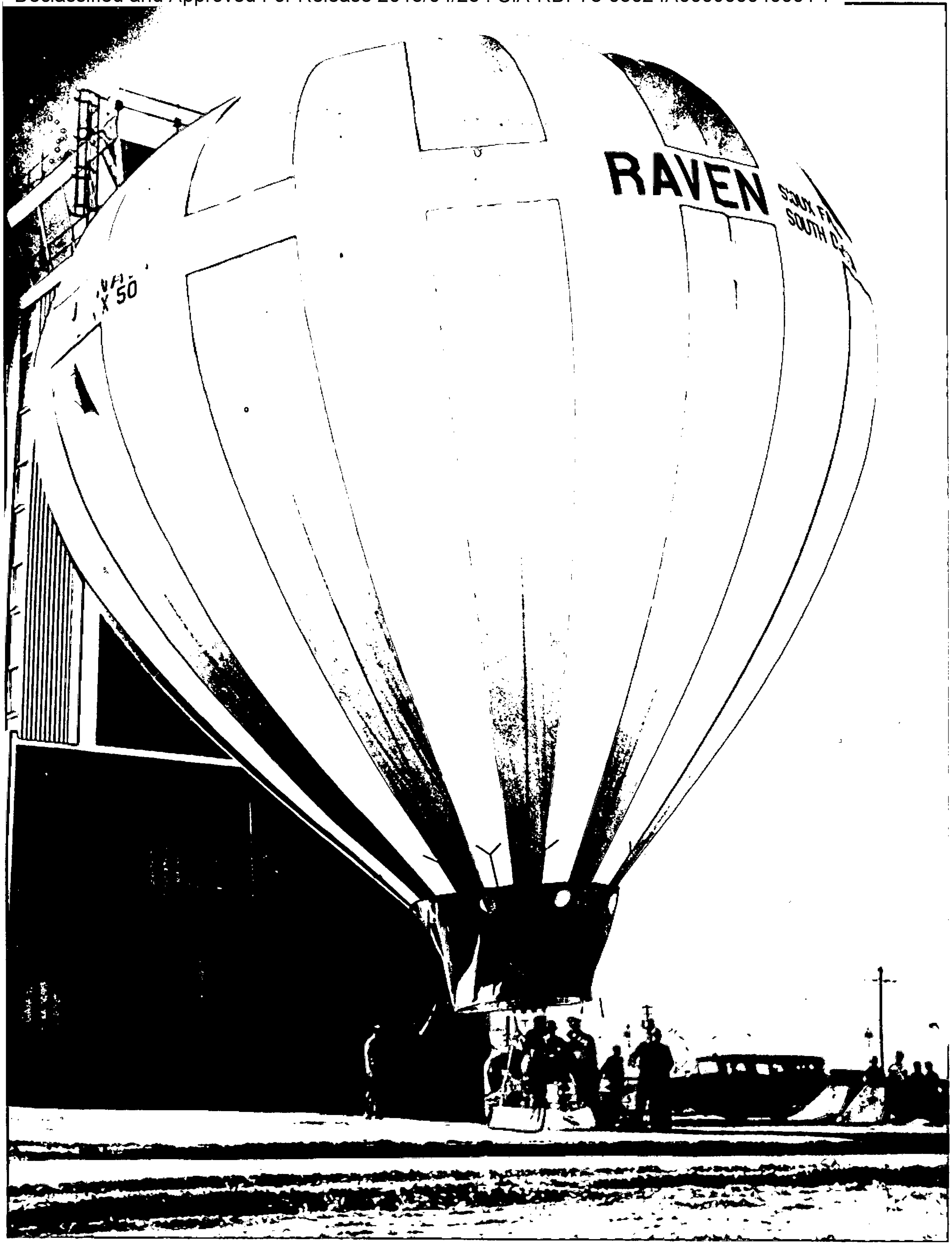

Figure 1 - CA-50 Balloon; inflated 21 September 1962

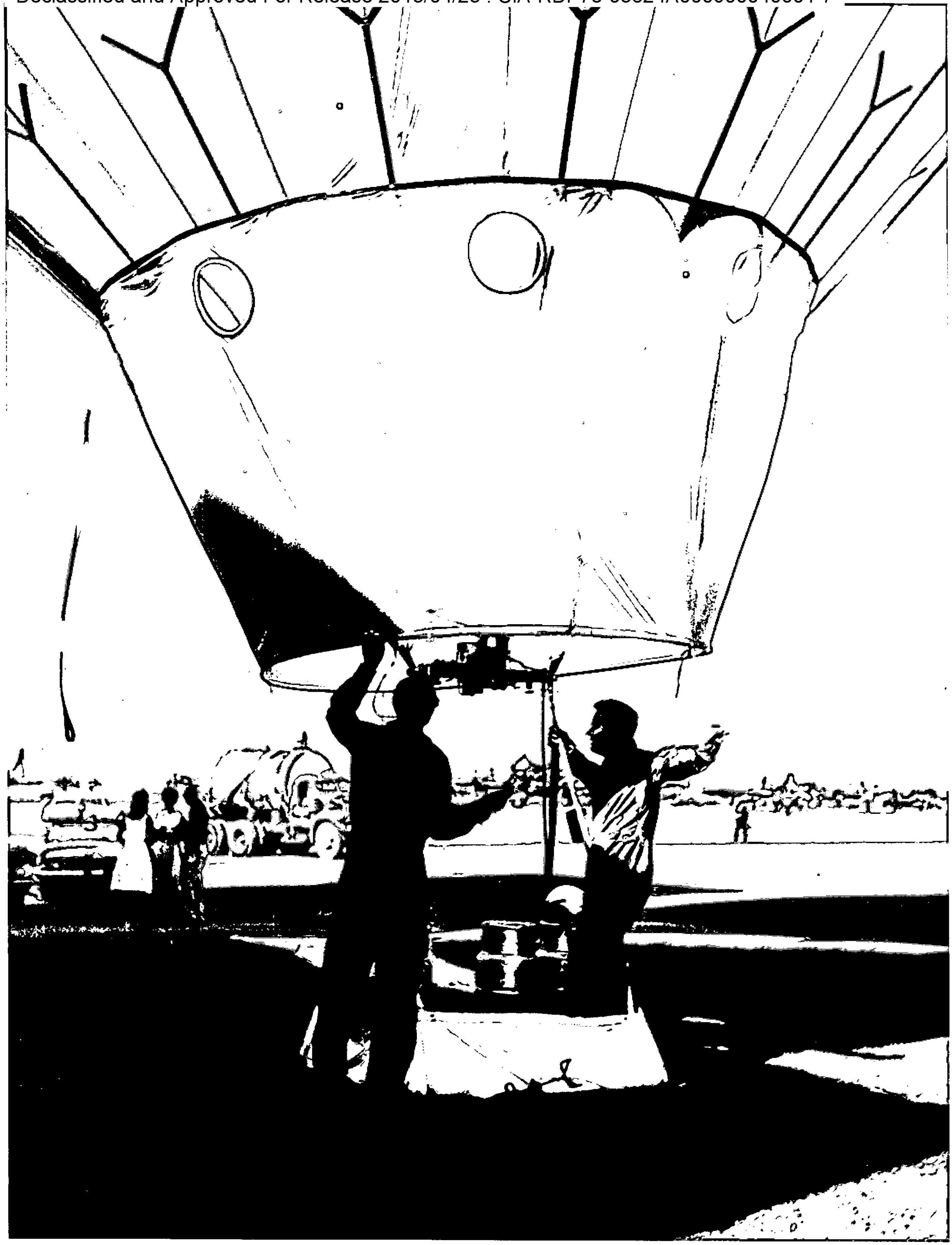

Figure 2 - Two-man Gondola; used 21 September 1962

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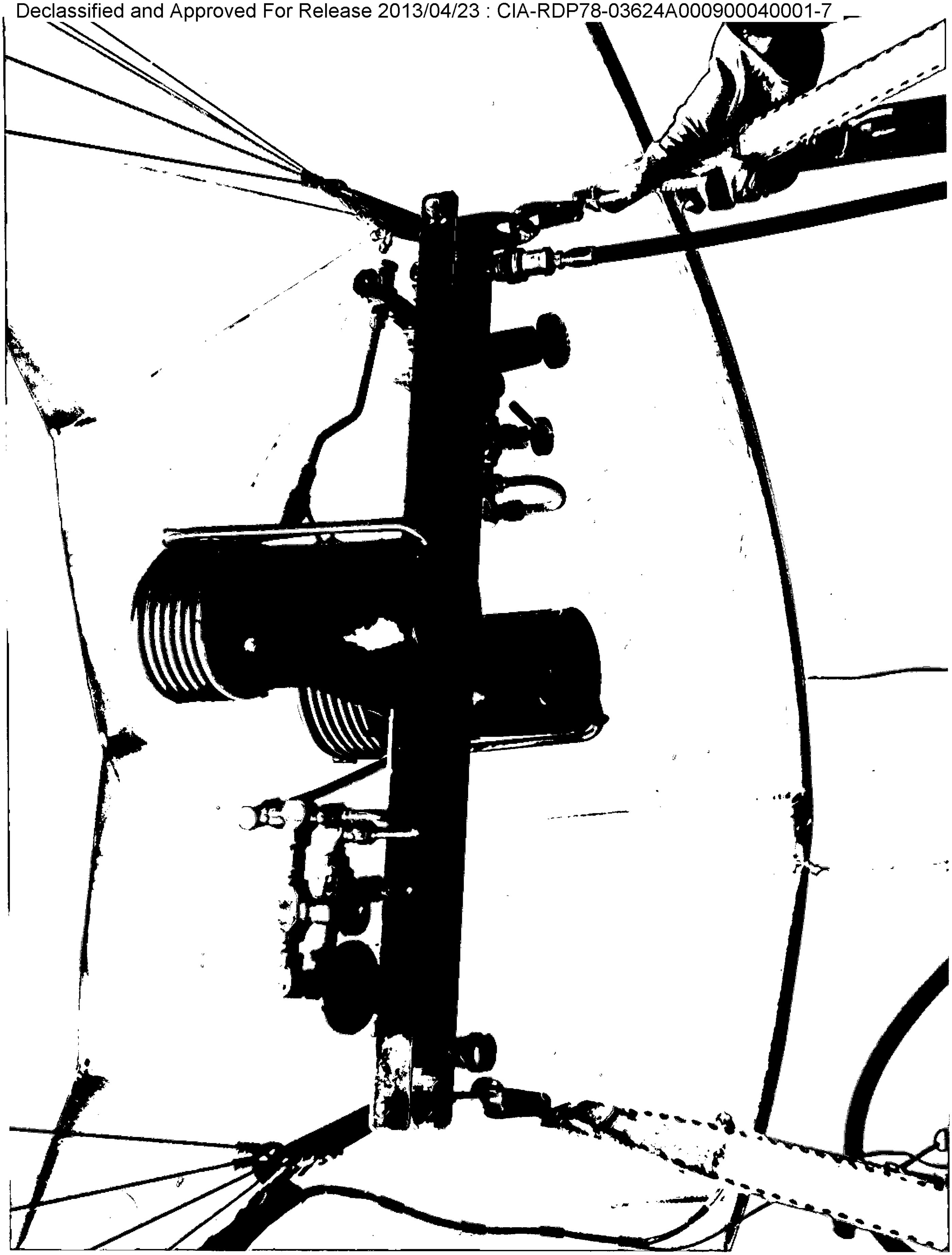

Figure 3 - Load Bar, Burner Assembly and Balloon Base

6,500 feet MSL, the average internal temperature did not exceed 220°F. This was determined by a continuous reading gauge attached to a thermocouple suspended inside the balloon near the crown. Earlier tests indicated that the average ambient temperature in the balloon was nearly equal to the highest skin temperature, at the crown. With the CA-50 balloon and the gondola, this temperature indicator was one of three elements which were newly developed for the 21 September test.

The next major tests were made from South Dakota on 16-18 October, 1962. The equipment used was virtually the same as that flown in Las Vegas. The objective of the first test included an evaluation of flight characteristics at night, and determination of the need for a flashing red light to provide visibility for other aircraft. All balloon system functions performed well at night, although considerable difficulty was experienced in selecting a landing spot. There was no moon, and the wind just above the ground was above 20 mph. Coupled with a long reaction time in the balloon heat capacity, this resulted in the balloon "over-flying" the distance in which visibility was adequate for landing.

Standard aircraft red flashing lights were carried on board and were visible for several miles. They were almost indispensable in locating the balloon. When the red lights were turned off, the balloon took the appearance of a fast moving star, at distances of one quarter of a mile and at an altitude of 2,000 ft. above the terrain. At about one-half a mile, even veteran observers on the ground lost the balloon entirely. It is of interest to note that these same distances marked the limit of audibility. Within 1/4 mile, the balloon burner could be heard, at 2,000 ft., but it was not audible much beyond that, certainly not at 1/2 mile. To complete this test, the ACW radar site at Chandler, Minnesota, was advised that the balloon would be within 50 miles of the station. Actually, the flight trajectory, east from Parker, South Dakota, passed about 30 miles south of the radar. No detection was made.

The failure of the radar to pick up this balloon resulted in a second test, on October 18, 1962. Then the same balloon was flown from Sioux Falls, South Dakota, and maneuvered so as to pass within visual sight of the ACW station. The duty officer was advised of the balloon flight and made several attempts to locate it by radar. No success was obtained, although station personnel were able to see the balloon at one time.

Coming as they did, soon after the Las Vegas flight, the October flights were made before any changes had been made in the system. The following three months saw the development of many new elements. These included:

A new burner
A new balloon material
A smaller ground inflation unit
A new gondola
A new squib firing mechanism
New fuel tanks, and
A new balloon construction feature to enhance maneuverability (called a maneuvering valve, vent or slit)

The design of a burner suitable for use in flight on a hot air balloon was fundamental to the development of the earlier one man system. The choice of a common fuel, the use of liquid delivered under pressure to the burning area, preheating, a pilot light, and the one man system burner design were all described in an earlier report (Raven Report 1863). For the increased heat requirements of the two man unit, the same basic principles were applied, but the flow rate was more than doubled. Propane provides 20,000 Btu per pound, (4.25 pounds to the gallon). The new burner was designed to operate at about 10 gallons (42.5 lbs. - 850,000 Btu) per hour, with a maximum flow rate of about three times this (2,200,000 Btu per hour).

Figure 4 and prints in Appendix IV show the burner as developed. Included in Appendix V are some of the data used to design this burner. Sheet V-1 shows the lift of hot air as a function of ambient and internal temperatures. This leads to a calculation of the heat required to elevate the air temperature. Sheet V-2 relates the air

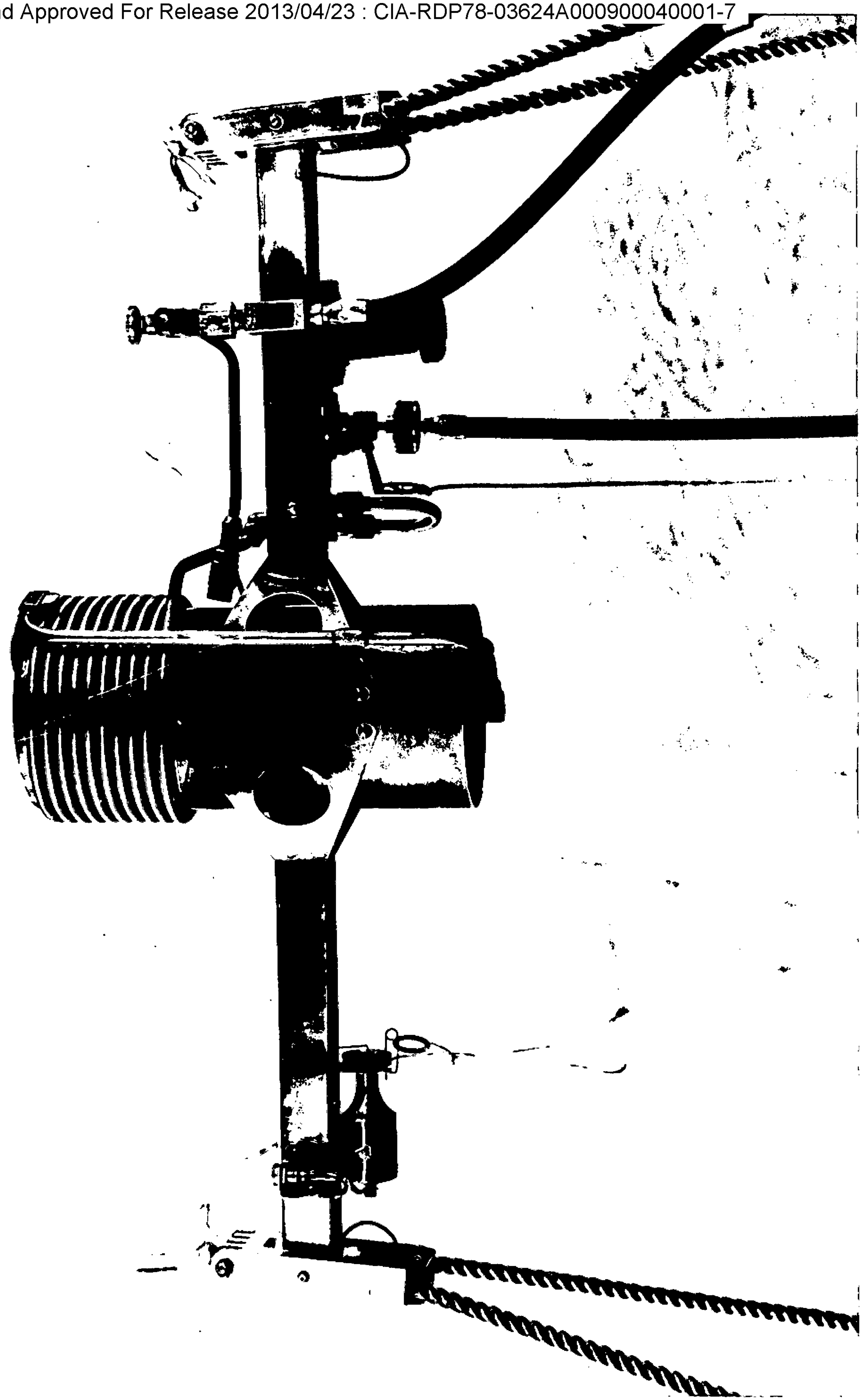

Figure 4 - Improved In-flight Burner for CA-50 System

flow required as a function of heat output, and Sheet V-3 shows the total orifice area versus heat flow, as a function of fuel line pressures. Consideration of these basic parameters - line pressure, orifice size, air entrainment and total heat requirement - led to the design of the burner. Also included in Appendix V is a test report of burner performance. This burner, like its one man system predecessor, was fed by dual flow lines, one regulated by a vernier for slow adjustments in the heat output and one for full on full off operation.

While the new burner was being developed, a new balloon material was being tested. This material, nylon coated with acrylic, weighs .010 lbs. per sq. ft. as compared with the heavier Mylar-nylon laminate which was used for the first CA-50 balloon (.013 lbs. per sq. ft.). An analysis of these materials is presented in Appendix VI. This material is considerably lighter than the laminate, and nearly equal in strength.

The disadvantage in weight, plus the tendency of the nylon-Mylar material to delaminate was eliminated by the adoption of the acrylic coated nylon. Two new CA-50 balloons were built (Figure 5) under this project, using the acrylic material. Although they were all white, it is entirely possible to obtain this material in colors.

One of the objectives of this project was the reduction of weight to permit easier handling in the field. Three new elements contributed

Figure 5 - CA-50 Balloon, made from Nylon Coated with Acrylic

to this end. Special stainless steel fuel tanks, with fuel quantity indicators, were made to order. These tanks were designed to withstand 400 psi, with a safety valve set at about 250 psi. At 100°F propane has a vapor pressure of 187 psi. Two sizes - 22 gallons, and 30 gallons were procured, in quantities of two each. (See Figure 6).

A major weight reduction was effected by the replacement of the remote air heater and blower. A small gasoline-driven blower weighing only 7.5 lbs. (Figure 7) was designed to use directly with the in-flight burner. The danger of singeing the balloon skirt was recognized, but experience has shown that the blower-burner operator can normally control the open flame, even with winds of 10 mph during inflation. For use, the blower is locked in place on the burner bar. It is easily removed and is not carried during the flight (see Figure 8).

A new gondola was designed to reduce weight. Pictured in Figure 9, it consists of a 60" x 46" laminated plywood sandwich filled with polyurethane foam. Drawings are included in Appendix IV. The floor is curved, and an ingenious load support system was developed to decrease landing shock in high winds. The gondola is normally supported by nylon lines attached at the four corners. The lines pass from the corners to two lock points; one in the center of each 60" side. Upon touch down, the curved gondola will slide along the ground. The up-wind lock is then released, allowing the gondola to

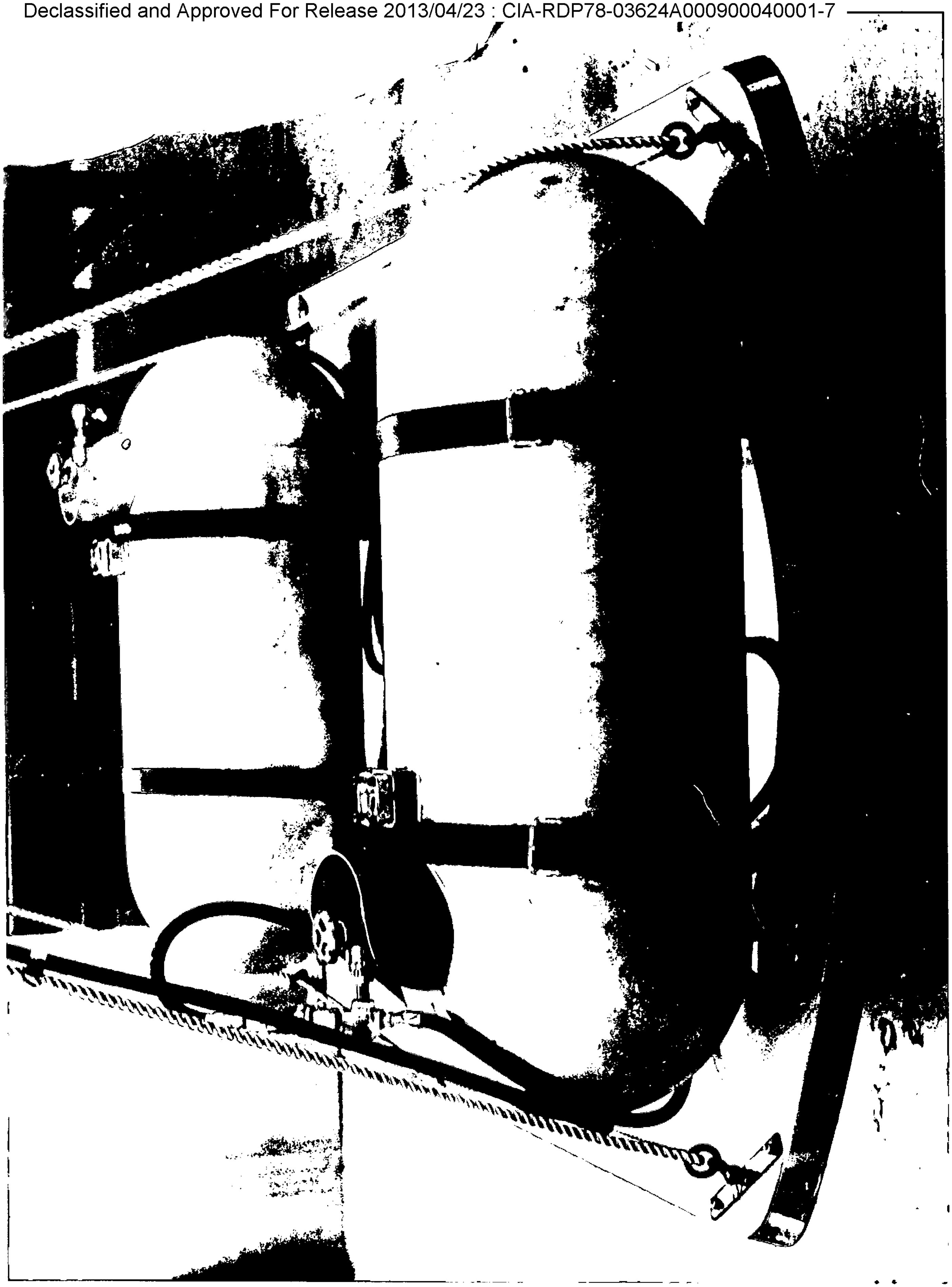

Figure 6 - Standby Steel Fuel Tanks

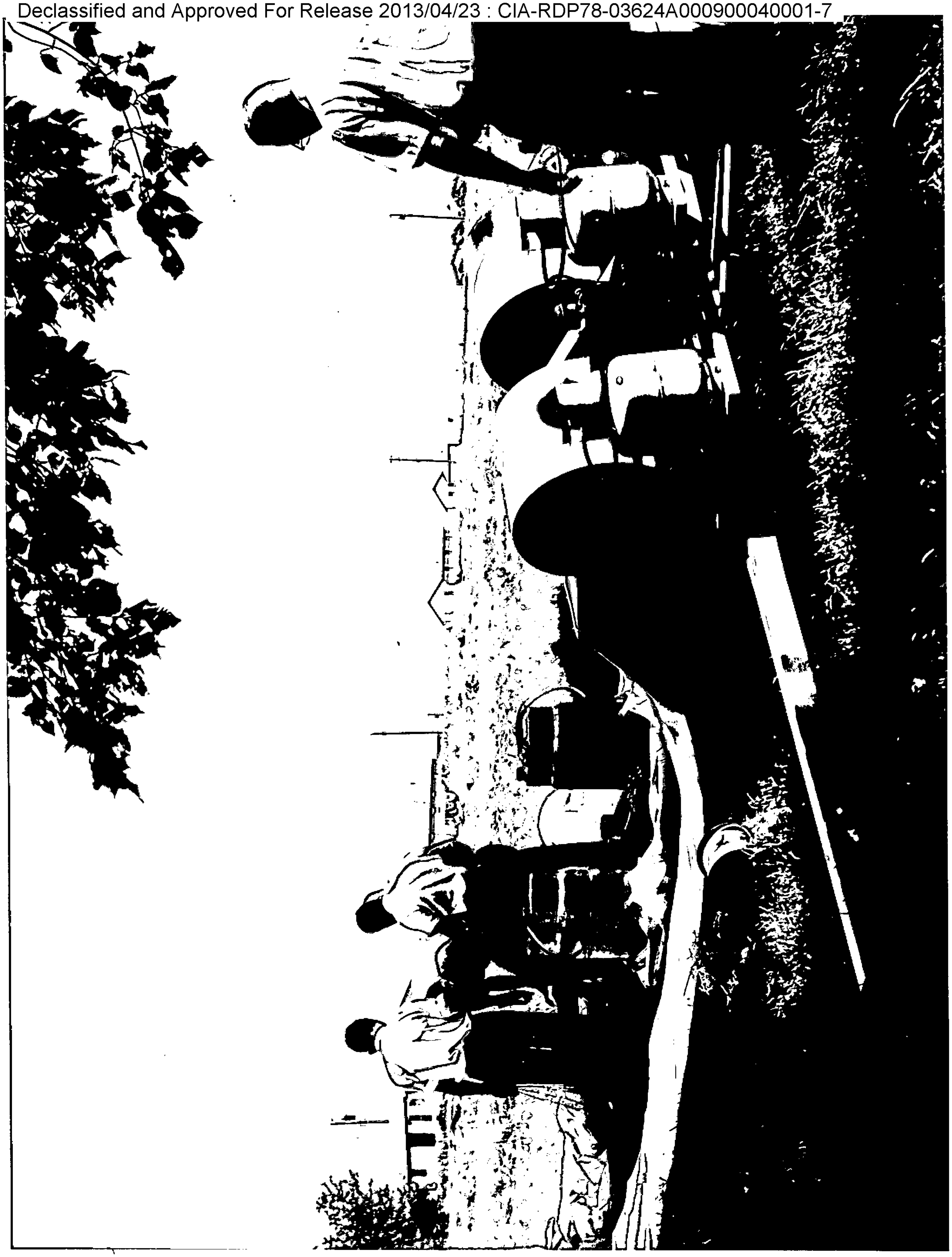

Figure - 7 Remote Heater and Blower

Figure 8 - Light Weight Blower in Use During Inflation

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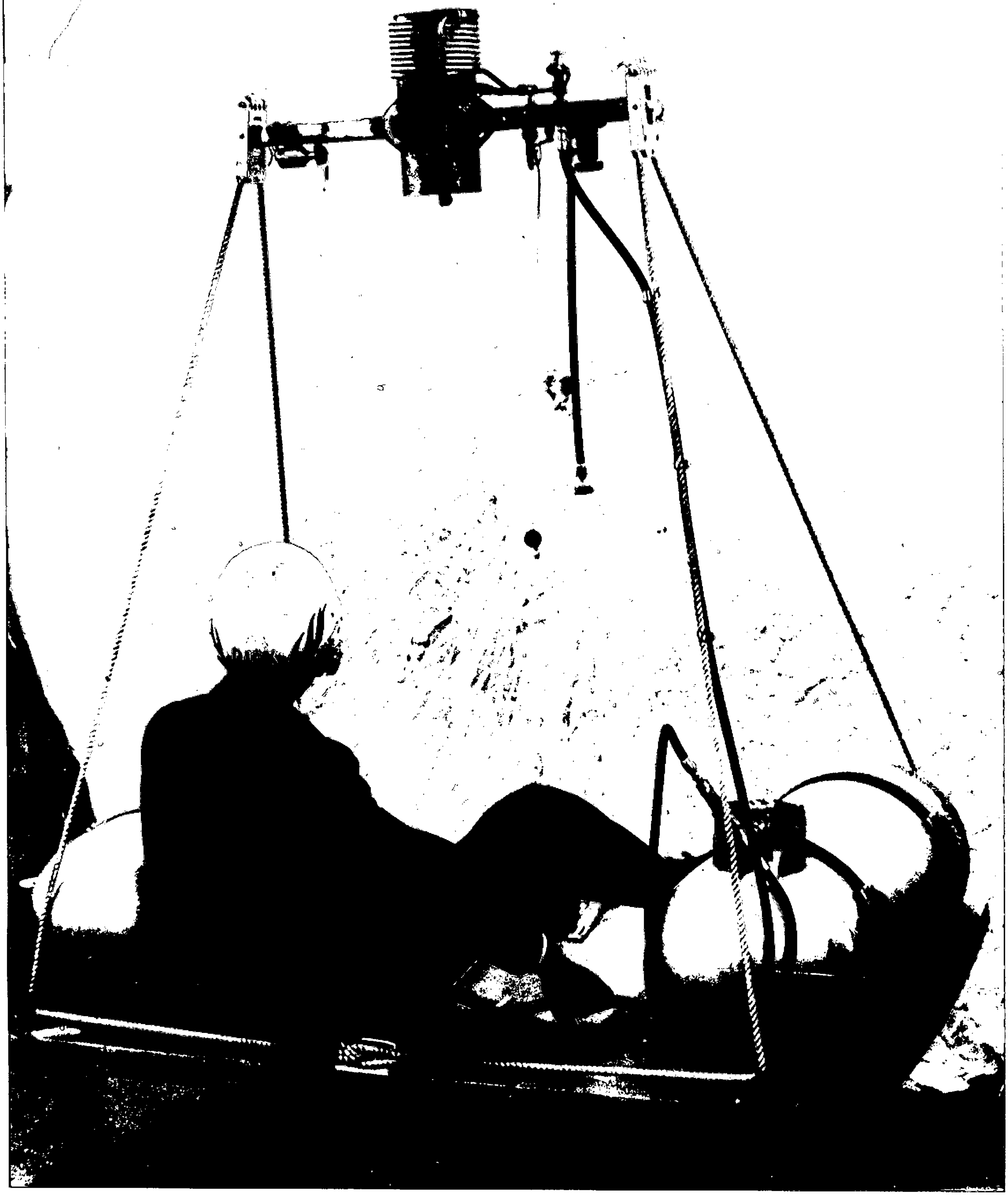

Figure 9 - Two-man Curved Floor Gondola

act like a surfboard, protecting the crew while the balloon slows down prior to and during inflation.

The two other innovations to the system during the last quarter of 1962 did not affect weight of the system, but both added to its utility. A new electric generator, operated by a pull cord, replaced the flashlight cells used to fire the squib and open the top of the balloon upon touchdown. This eliminates the problems of batteries becoming stale, or cold, and not working.

As a result of the problem of maneuverability at night, brought out by the October test, increased control over the balloon was sought. The burner has excess capacity so that a relatively rapid response can be induced, when more lift is needed. Cooling, however, is a slow process, with more than a ton of air inducing lag in the heat balance of the system. To provide a capability for more rapid descent, so that shorter fields may be used for landing, it is necessary to cool the air quickly. The technique devised to accomplish this consists of opening a vertical slit in the side of the balloon. This vent, 20 feet long, is opened manually by a line running down to the gondola. The vent closes because the shape of the balloon has been calculated to provide near zero horizontal stresses in the skin. Thus the vent is held shut by the vertical skin stresses. In a balloon which has horizontal stress, the vent would not close, and the balloon would continually lose lift. To keep it closed during inflation, before the full shape has been developed, a cloth zipper material, Velcro, is used. Figure 10 shows the vent in a partially open position. This device has proven extremely useful, and now the pilot can quickly replace hot air with cooler air and greatly increase the maneuverability of the system.

All of these seven features were included in the system. Two balloons, one new white acrylic CA-50, and one (used in September) of orange and white Mylar and nylon, with the descent vent incorporated were taken on a field trip to Albuquerque, New Mexico. In the week beginning 5 January 1963 these two balloons were used for four flights, averaging two hours in duration. Basic equipment designs were satisfactory but a number of minor changes and improvements were planned. These included:

1. Modify the top tie off on the white balloon; change prints.
2. Install the side vent with the white balloon and test.
3. Weld carrying handles on fuel tanks.
4. Install fuel screen in both burner assemblies.
5. Replace leather fuel tank hold down straps with nylon straps.
6. Install protective screen around blower assembly.
7. Modify the gondola board rope release assemblies.
8. Change safety pin attachment on rope release mechanism.
9. Sew VELCRO on both sides of balloon side vent.
10. Make 4 bungee attach lines between balloon skirt and gondola.
11. Rework the Poeschel ring end attachments.
12. Calibrate the fuel tank quantity gauges.
13. Replace one of the 30 gallon fuel tank gauges.
14. Add safety lock to the main fuel line quick disconnect.
15. Provide dust cover for fuel line quick disconnect.

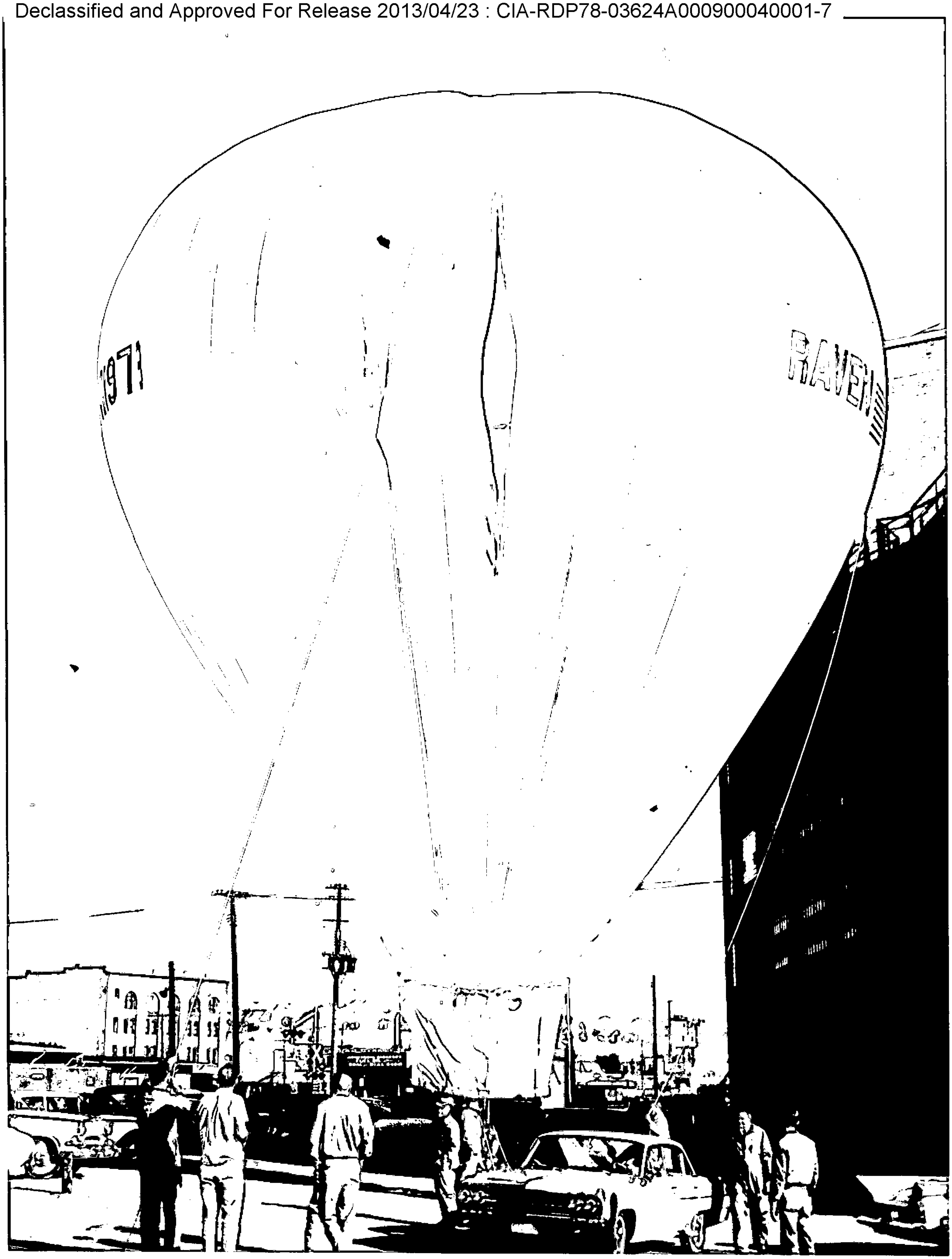

Figure 10 - Side Vent for Maneuvering

16. Conduct experiments in quieting burner noise.
17. Examine means of preventing condensation from dripping on crew.
18. Design new balloon carrying bag.
19. Modify gondola board corners, add device to prevent tank sliding. Add additional tank support if required.
20. Add second Poeschel ring at bottom base for inflation trial.
21. Add holes within burner chamber for increased vaporization capability.
22. Stiffen burner assembly.
23. Procure electrical fuel valves for automatic flight control.
24. Add fuel pressure gauge to burner assembly.
25. Conduct auto pilot flight test.
26. Conduct a flight endurance test.
27. Lengthen the bridle lines on the orange and white balloon side vent.
28. Rotate skirt on white balloon, to align with gondola corners.
29. Install brass needle valves on both burner assemblies.

Of these 29 objectives most were completed within the next six months. Two items, the bungee line and a second Poeschel ring (Items 10, 20) were tried but not found especially valuable, and have not been put in general use. Although electrical fuel valves were procured (Item 23) they were not built into an autq pilot system, and no auto-pilot flight was made (Item 25). Likewise, no special duration flight (Item 26) was made. Three other items were not carried out. These were items 14, 16 and 17; fuel line connector lock, noise abatement and condensation shield.

Many of these changes were readily accomplished, and were carried out without difficulty. A number of flights were made to supplement and check designs and calculations. Most of these flights were made from Sioux Falls, South Dakota, but one notable flight was not. This was made with the white CA-50 balloon, used in January. Here, the two man system was employed in a demonstration flight across the English Channel, under another project. The flight covered the distance from Rye, England, to Gravelines, France, 90 miles in 3.5 hours on April 13, 1963. The pilot was forced to rise to 13,000 feet to find favorable winds, and to utilize the side vent to build up descent velocity to over 1,000 feet per minute in order to land within France. The performance of the system was most satisfactory on this occasion.

With the completion of 24 of the 29 changes suggested in January, all development work was ended. On 11 June 1963, a final system check flight was made, from a flight center near Sioux Falls, South Dakota, (Larchwood, Iowa). Winds of about 15 mph were encountered and a crew with only limited experience successfully accomplished inflation and launching. The balloon was damaged in a fence after landing. Nevertheless, the ability of relatively untrained crewmen to operate this system was demonstrated.

Although prints and drawings were still being completed after this date, the flight of 11 June marked the end of the development program.

The longest flight yet made with a two man system was conducted under another program on 26 June, 1963. Here a single pilot used the system, as developed, and covered some 120 miles from La Junta, Colorado to Kanorado, Kansas, in exactly four hours.

It should be noted that this project has been basic to other programs, concurrent and subsequent, in which hot air balloons are now being used, or are under study. In recognition of these conditions, a recent report entitled "A Summary of Hot Air Balloon Technical Data" is attached, as Appendix VII

Appendix I

Appendix I

Project 297

Residual Materials Inventory

Balloons

2 ea., 50 ft. white nylon envelopes, treated with acrylic, equipped with side vent, squib top tie-off condition; 1 new; 1 used, good.

1 ea., 50 ft. orange and white nylon-Mylar laminate equipped with side vent, squib top tie-off condition: used, fair.

Gondola boards

2 ea., complete with rigging to attach to balloons condition: 1 new; 2 used, good.

Fuel tanks

2 ea., 30 gallon stainless steel, with quantity indicator condition: used, good.

2 ea., 22 gallon stainless steel, with quantity indicator condition: used, good.

Burner Assemblies

2 ea., complete with plumbing and controls, condition: used, good.

Ground Inflators

2 ea., gasoline powered, hand-held, portable condition: used, good.

Instruments

2 containers

2 thermocouples and leads

2 altimeters, Kollsman sensitive type

2 rate-of-climb indicators, Kosim variometer type condition: used, good.

Balloon Bags

3 ea., canvas with carrying handles condition: used, good.

Parachute

1 ea., 28 ft. personnel, white canopy condition: used, good

Project 297
Residual Materials Inventory

<u>Storage Boxes</u>
2 ea., adequate to contain all of above inventory.

<u>Components</u>
Hardware, 2 solenoid valves (for auto-pilot) not assembled.

Appendix II

Appendix II

Check list for hot air balloon operations.

I. Preflight preparation

A. Checkout instruments

1. Altimeter
2. Variometer
3. Thermocouple
4. Squib line continuity
5. Clipboard with paper and pencil
6. Wind gauge
7. (Binoculars, cameras)

B. Fill fuel tanks

1. Propane
2. Blower engine (regular gasoline with oil (10 parts to 1))

C. Prepare balloon

1. Tie off top
2. Close side vent
3. Connect squib

D. Check gondola and fittings

1. Rigging lines
2. Board
3. Tank support
4. Burners
5. Switch and safety for squib
6. Pins, for safety of rope release

E. Check fuel system

1. Clear propane lines, including pilot line, check quantity (marked in gallons, 4 lbs. to a gallon)
2. Start and operate blower engine

F. Weather Check

1. Determine wind field
2. Pick launching site
3. Collect flight maps
4. Plan recovery operation

G. Crew briefing, (includes ground crew)

II. Flight layout

1. Lay out balloon
2. Bring all handling lines outside skirt
3. Arrange risers so that squib line riser comes to right side of burner bar, while burner bar is lying with blower pin slots up
4. Attach burner bar to balloon risers
5. Snap in ropes to burner bar, then connect to gondola, fastening at corners so that fuel line connects to tank outlet.
6. Install sideboards, attach two downwind sides with bungee
7. Hook up thermocouple
8. Install Poeschel ring in skirts
9. Connect fuel lines to tanks and check burner fuel flow

III. Inflation

1. Position available crew, 1 man operates blower and burner, 1 man holds skirt open. One man (if available) holds crown out, and restricts balloon sail effect by diverting air into crown. Other men (if available) hold handling lines, and help hold gondola down.
2. Turn on blower, and start to fill.
3. As soon as throat is distended, turn on fire. Fill balloon at low to moderate flame, watch that skirt and balloon throat do not get singed.

Appendix III

Appendix III

Outline of Hot Air Balloon Pilot Training Program

Date	Time	Topic	Instructor	Hours	
June 12 Wednesday	0900-1200	Introduction, Flight Theory, Aerostatics	JAW	3	
	1300-1600	Meteorology	Friz	3	
	1600-1900	Equipment Familiarization	DP/TP	3	9
June 13	0900-1200	Meteorology	Friz	3	
	1300-1500	Navigation	JPD	2	
	1500-1800	Equipment Familiarization	DP/TP	3	8
June 14	0900-1200	Meteorology	Friz	3	
	1300-1500	Navigation	JPD	2	
	1500-1800	Physical Examination, Field Test (maybe in Arena)	DP/TP/JRS	3	8
June 15	0500-1000	Field Test/Pilot Balloons	DP/TP/JPD	5	
	1000-1300	Meteorology	Friz	3	8
June 16	0500-1500	Field Test/Pilot Balloons	DP/TP/JPD/JRS	10	10
June 17 Monday	0900-1200	Meteorology	Friz	3	
	1300-1700	Paper Balloons	JAW	4	
	1900-2300	Pilot Balloons	JPD	4	11
June 18	1000-1200	FAA Regulations	DP	2	
	1300-1600	Meteorology	Friz	3	
	1600-1800	Navigation	JPD	2	7
June 19	0500-1000	Field Test/Pilot Balloons	DP/TP/JPD	5	
	1000-1200	Meteorology	Friz	2	
	1300-1500	Navigation	JPD	2	9
June 20	0500-1200	Field Test/Pilot Balloons	DP/TP/JRS	7	
	1300-1600	Meteorology	JRS	3	10

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Outline of Hot Air Balloon
Pilot Training Program

Date	Time	Topic	Instructor	Hours	
June 21	0500-1200	Licensing by FAA Inspector/ Pibals	DP/TP/JRS	7	
	1300-1600	Meteorology	JRS	3	
					10
June 22	0500-1200	Field Test/Pibals	DP/TP/JRS	7	
	1300-1600	Meteorology	JRS	3	
					10
June 23	0500-1500	Field Test/Pibals	DP/TP/JRS	10	
					10
June 24	0500-1200	Field Test/Pibals	DP/TP/JRS	7	
	1300-1700	Meteorology	Friz	4	
					11
June 25	0900-1300	Meteorology	Friz	4	
	1700-2400	Field Test/Pibals	DP/TP/JRS	7	
					11
June 26	0900-1200	Meteórology	Friz	3	
	1300-1700	Course Critique	Students/Staff	4	
					7

Summary of Training Hours

Introduction, Theory of Flight, Balloon Systems	3
Equipment Familiarity	6
Navigation	8
Paper Balloons	4
Pilot Balloons, Theory and Practice	4
Meteorology	40
FAA Regulations	2
Field Tests, Pilot Balloon Practice, Helium Balloon Flight	68
Course Critique	4
	139

Staff

JAW	James A. Winker, Chief Engineer, Raven Industries, Inc.
Friz	Dr. Emily Frisby, Director of Meteorological Research
DP	Don Piccard, Manager Thermal Balloon Program
TP	Tom Pappas, Sr. Engineer
JPD	Jack Donaghue, Sr. Engineer
JRS	J. R. Smith, Vice President
PEY	P. E. Yost, Vice President

Appendix V

(Appendix IV is bound separately)

Appendix V

8 June 1963

Pre-flight Tests of Hot Air Balloon Burner

Tests of this burner were performed on test stand shown in photos. Tests were run in the south end of the parking lot. The following functions were tested:

1. Maximum flow test. With the pilot light on, the adjustable flow valve open six turns and the maximum flow valve closed, the burner was run three minutes to allow full warmup of the burner. After warmup, the fuel tank was weighed and immediately after weighing time was started and the maximum flow valve opened. Indicated operating pressure during these tests was 77-78 psig and the test was stopped as soon as the operating pressure showed a drop. The following results were obtained.

Time	Fuel Used	Rate
8.9	17.5	1.97 lbs./min.
15.35	28.0	1.83
16.00	30.00	1.87
14.61	29.0	1.98
14.95	29.0	1.94
Avg. 69.81	133.5	1.91 lbs./min. = 2,292,000 Btu/hr.

During the test the ambient temperature was 90-95°F and the wind was 6-8 kts. estimated. The flame was colorless up to about 20 inches from the top of the burner where there was an orange band of color one to two inches in thickness. There was no odor of unburned gas. Plumbing at the base of the burner was hot to the touch but not hot enough to burn the finger. Condensation was very heavy on the first three coils and tapered off to nothing over the next three coils. No frost was formed on any coil.

2. Cycle tests. Low fire to maximum flow. With the pilot light on, the adjustable flow valve open six turns, and the maximum flow valve closed, the burner was run for three minutes to allow full warmup. Then the maximum flow valve

was continuously opened for five seconds and closed for five seconds. This cycle was continued for thirty cycles. Except for a marked odor of raw gas being present, the remarks in test one equally apply.

Cycle tests. Pilot light to maximum flow. With the pilot light on, and the adjustable flow valve closed, the maximum flow valve was continuously opened for five seconds and closed for five seconds. Ten such cycles were run to allow for full warmup of the burner and the test was run for thirty more cycles. The remarks in test one equally apply. There was no odor of unburned gas.

The burner may have been burning unevenly. Carbon deposits formed on the mounting brackets from oil on the aluminum surface have been burned off completely on one side and incompletely on the other side as the attached photos show. The side that has been burned off completely was on the upwind side.

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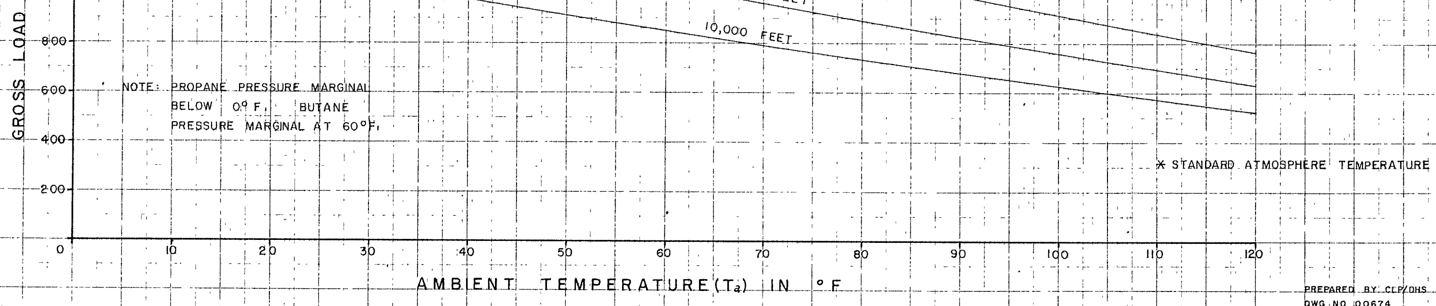
MAXIMUM AUTHORIZED OPERATING LIMITS

CA-50 BALLOON

ASSUMPTIONS:

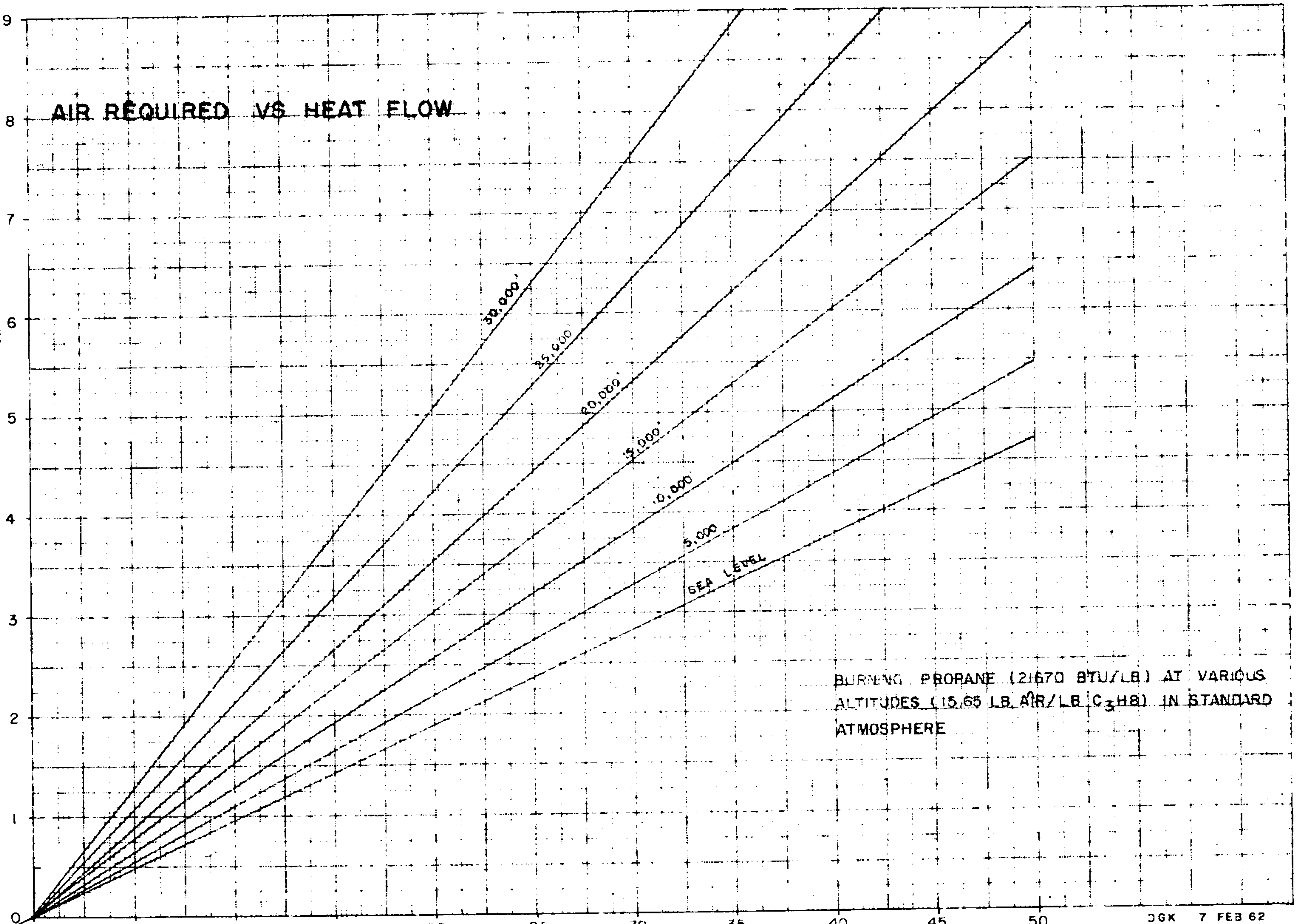
BALLOON VOLUME = 60,900 CUBIC FEET
BALLOON INTERNAL TEMPERATURE (T_b) = 250°F (MAXIMUM PERMISSIBLE FOR SUSTAINED OPERATION)
STANDARD A.R.D.C. PRESSURES



PREPARED BY CLP/DHS
DWG. NO 00674
14 JUNE 1963

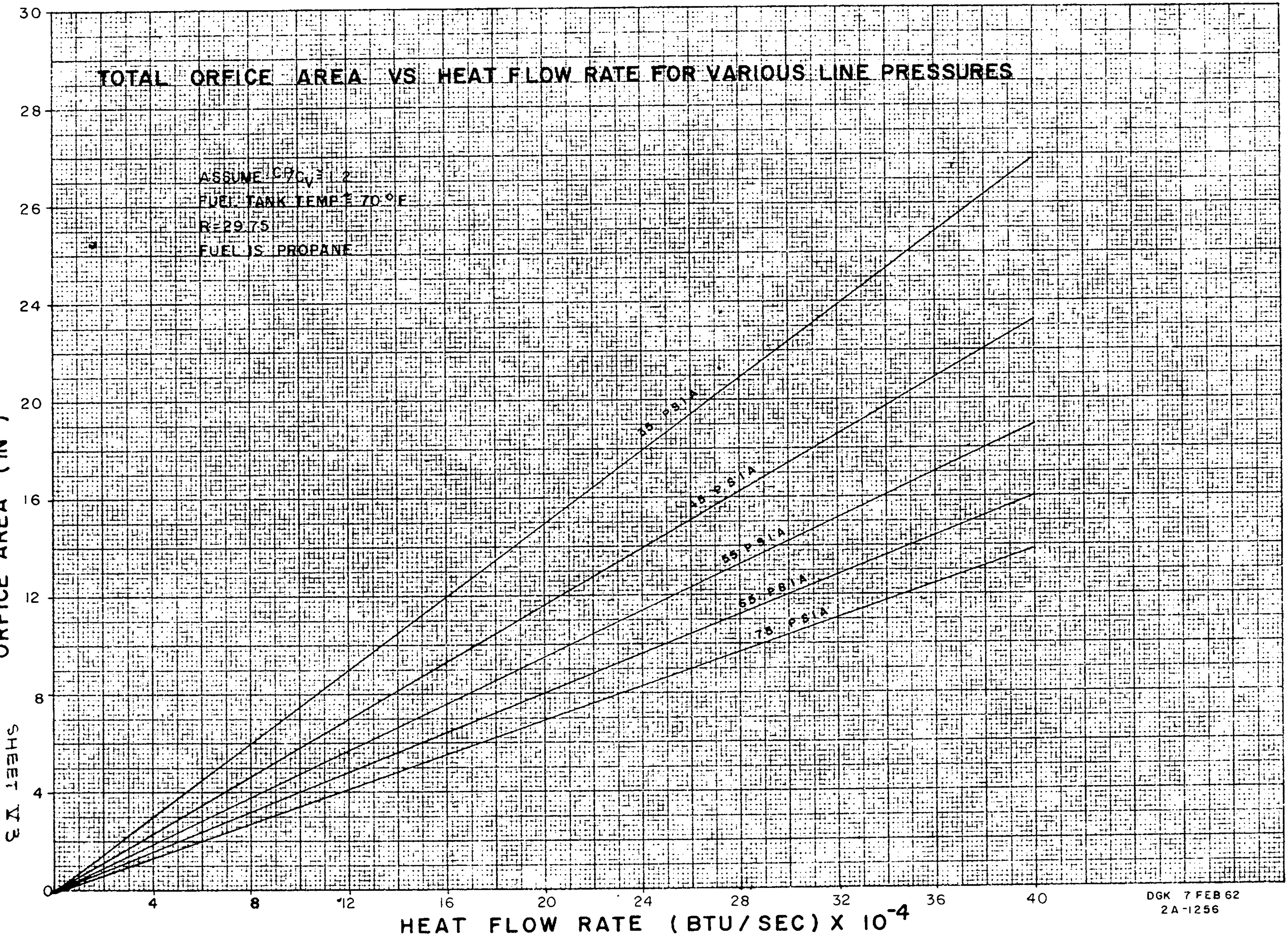
RAVEN
industries, inc.

SHEET V-1



SHEET 1 2

Declassified and Approved For Release 2013/04/23 : CIA-RDP78-03624A000900040001-7



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2A-1256

SHEET V 3

Declassified and Approved For Release 2013/04/23 : CIA-RDP78-03624A000900040001-7

Appendix VI

APPENDIX VI

TEST OF TWO HOT AIR BALLOON MATERIALS

Raven Industries Technical Note 30

29 August 1962

John A. Peasley

Engineering Department

Declassified and Approved For Release 2013/04/23 : CIA-RDP78-03624A000900040001-7

I. INTRODUCTION

A new hot air balloon material was ordered. This material is an acrylic coated 1.1 ounces per square yard rip-stop nylon fabric from Aldan Company. It was tested along with 0.35 mil Mylar laminated to 1.1 ounces per square yard rip-stop nylon fabric bought from Acme Backing Company. The Acme material has been used successfully in previous hot air balloons. If the Aldan material has satisfactory properties its 23% lower unit weight would be advantageous in many applications.

II. TEST RESULTS AND PROCEDURES

Fabric weight was measured on one square yard of material with the gram balance. The acrylic-nylon weighs 0.010 pounds per foot squared and the Mylar-nylon weighs 0.013 pounds per foot squared.

Room temperature tensile tests were pulled on both materials in the machine and transverse directions. The first tests were made using the standard tensile machine grips with masking tape on both sides of the specimens. The test results for acrylic-nylon are shown on sheet A and for the Mylar-nylon on sheet B. In the first test the acrylic-nylon tested 28.5 pounds per inch in the machine direction and 27.3 pounds per inch in the transverse direction while the Mylar-nylon tested 43.7 pounds per inch in the machine direction and 43.6 pounds per inch in the transverse direction. The results for the acrylic-nylon were lower than expected, but retests with a 1 7/8 inch wide sample did not change the results. The results with a 1 7/8 inch sample are not shown.

Later we developed a clamp that wrapped the material around a 0.5 inch diameter rod. Both materials were tested with this clamp as shown in the picture on sheet C. The results of the tests with the new clamp are shown on the bottom of sheet A and sheet B. With these clamps the tensile strength of the acrylic-nylon increased to 47.2 pounds per inch in the machine direction and 41.7 pounds per inch in the transverse direction. While the results for the Mylar-nylon had relatively minor changes to 43.5 pounds per inch in the machine direction and 48.4

pounds per inch in the transverse direction. It appears that the acrylic nylon is more sensative to the method of loading. When the acrylic-nylon material is used in a balloon, the design should be carefully reviewed to make sure the loading is as uniform as possible.

A fin seal was sewn in the machine direction of the material and pulled in the transverse direction for both materials. The results of this test are shown on sheet D. The acrylic-nylon failed at 21.1 pounds per inch of seam and the Mylar-nylon failed at 27.7 pounds per inch of seam. Both of these materials failed at about 50% of the parent material strength.

The final test run was a static-load temperature test. In this test two machine direction and two transverse direction samples were checked at three different loads. The loads used were 5 pounds, 10 pounds and 20 pounds. A typical test set up is shown on sheet E. The test procedure was as follows:

1. The samples were cut one inch wide and long enough to have at least a 2 inch gage length between the clamps.
2. A 2 inch gage length was marked at the middle of each strip of material.
3. The clamps were installed with strips of asbestos paper on both sides of the material.
4. Each strip was hung vertically and the gage length was measured with a Cathetometer and the length recorded.
5. Weights were hung on each strip for one hour and the gage lengths were remeasured and recorded.
6. The test strips were hung in the oven at 150°F with the weights attached and measured and recorded after one hour.
7. The temperature was increased 50°F every hour and the gage length measured every hour until the strip failed.

The test results for the acrylic-nylon is shown on sheet F and for the Mylar-nylon on sheet G. The percent elongation was calculated as the change from the original gage length after one hour at each load and temperature.

Both materials failed at approximately the same temperature at the same load. The acrylic-nylon had only minor elongations up to 250°F while the Mylar-nylon elongated uniformly up to 350°F. I do not see any advantages to either type of curve but it was characteristic of the materials. Also the acrylic-nylon showed consistently the biggest difference between the machine direction and transverse direction samples. I suspect part of this difference comes from the fact that the fill threads were not perpendicular to the warp threads on the acrylic-nylon material. It appeared that acrylic-nylon was less square than the Mylar-nylon material.

Sheets H and I are plots of break load versus temperature for both materials. These should be used as approximate information only, since the room temperature break was a dynamic load while the higher temperature failures were static loads. Both materials have approximately the same relationship between break load and temperature, so the nylon fabric must carry the major part of the load.

I have included as Annex I to this test report the prints for the 0.5 inch diameter round test clamp. This clamp appears to give good loading on the test strip and should be used in future tests. A picture of these clamps installed on a 1 inch strip is shown as Annex II.

An additional test of a balloon material is its tear strength. We used the A.S.T.M. D-39 procedure to measure the tear strength of these materials. This procedure lists two test methods and we chose to use the tongue method. In this test five 3 by 8 inch specimens are cut in the machine and transverse directions. A 3 inch long cut was made on the center line, starting at one of the 3 inch sides. One flap was fastened into each jaw of the tensile machine and pulled at 0.5 inches per minute with the pawls disengaged to allow the pendulum to follow the load. The test results are shown on sheet J. These results agree with the tensile tests of these materials, since the low tear strength and low tensile strength were in the same fiber direction.

III. SUMMARY

The acrylic coated nylon material from Aldan appears to be equal to the Mylar laminated nylon from Acme Backing in strength and temperature properties. The acrylic-nylon weighs about 23% less than the Mylar-nylon. Acrylic-nylon has only one shortcoming, we found, and that is its sensitivity to types or design of the loading clamp. With careful design this acrylic-nylon can be used, and the weight of the aerostat can be reduced.

Index to Attached Sheets

Sheet A

Room Temperature Tensile Tests of
Acrylic Coated 1.1 oz./yd.^{2} Rip-Stop Nylon
Fabric from Aldan Company

Material Weight 0.010 lb./ft.^{2}

First test with standard tensile machine grips

Sample No.	Machine Direction	Transverse Direction
1	26.4	29.8
2	33.5	34.0
3	30.2	26.6
4	22.0	30.5
5	29.5	22.4
6	29.4	19.4
Average tensile in lb/in	28.5	27.3

Second test with 1/2" round clamp

Sample No.	Machine Direction	Transverse Direction
1	47.5	41.7
2	46.8	42.5
3	47.5	41.8
4	47.4	41.5
5	47.0	41.0
6	47.0	
Average tensile in lb/in	47.2	41.7

Sheet B

Room Temperature Tensile Tests of
0.35 mil Mylar Laminated to 1.1 oz./yd.^{2} Rip-Stop
Nylon Fabric from Acme Backing Company

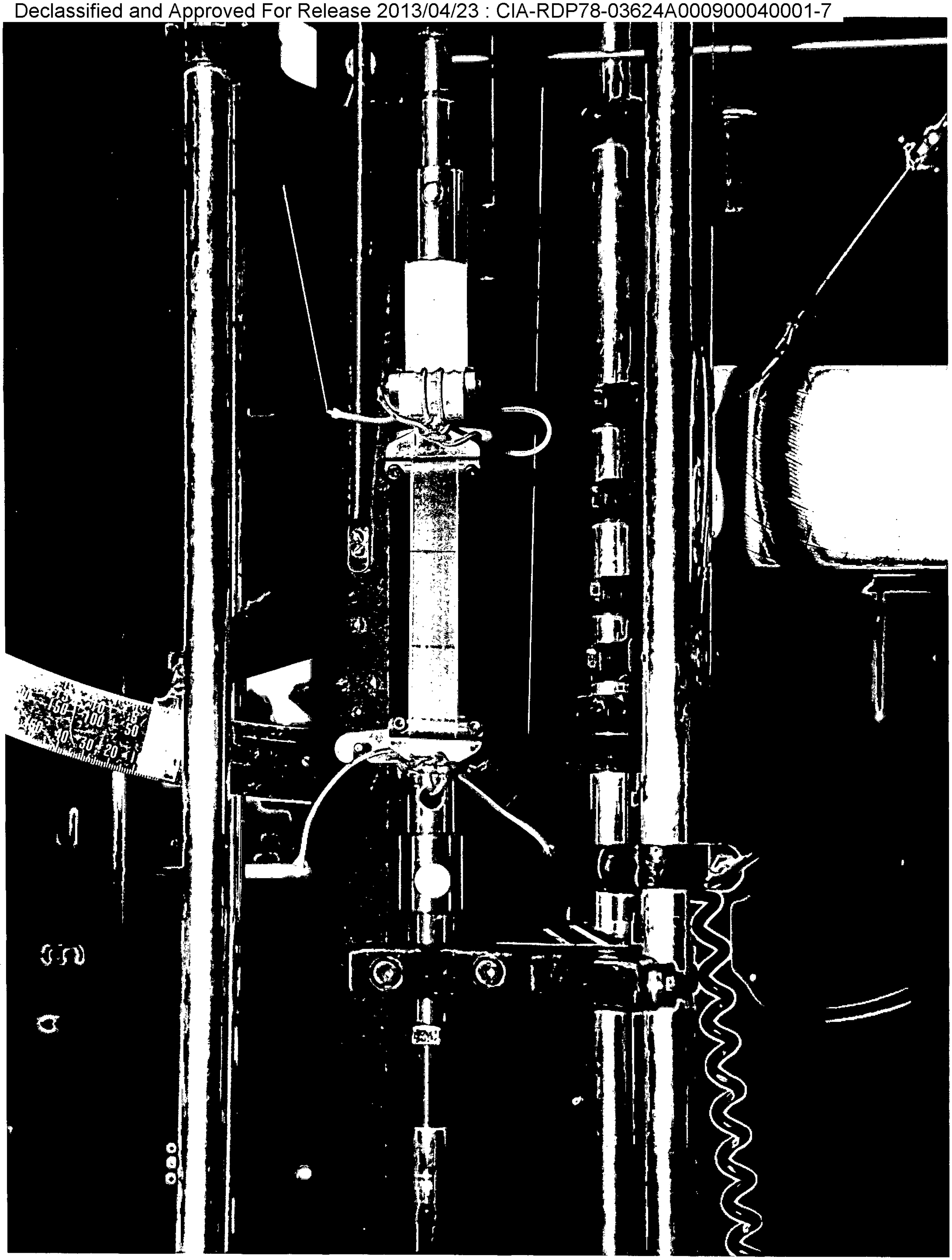
Material Weight 0.013 lb./ft.^{2}

First test with standard tensile machine grips

Sample No.	Machine Direction	Transverse Direction
1	45.4	44.9
2	44.0	40.4
3	42.8	40.2
4	44.2	42.5
5	42.6	45.0
6	43.2	48.5
Average tensile in lb/in	43.7	43.6

Second test with 1/2" round clamp

Sample No.	Machine Direction	Transverse Direction
1	42.5	48.8
2	42.8	48.8
3	43.2	48.5
4	44.2	48.5
5	44.8	47.5
Average tensile in lb/in	43.5	48.4



Tensile Test with 1/2" Round Clamp

Appendix VI
Sheet C

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Sheet D

Stitch Strength Test for Balloon Fabrics

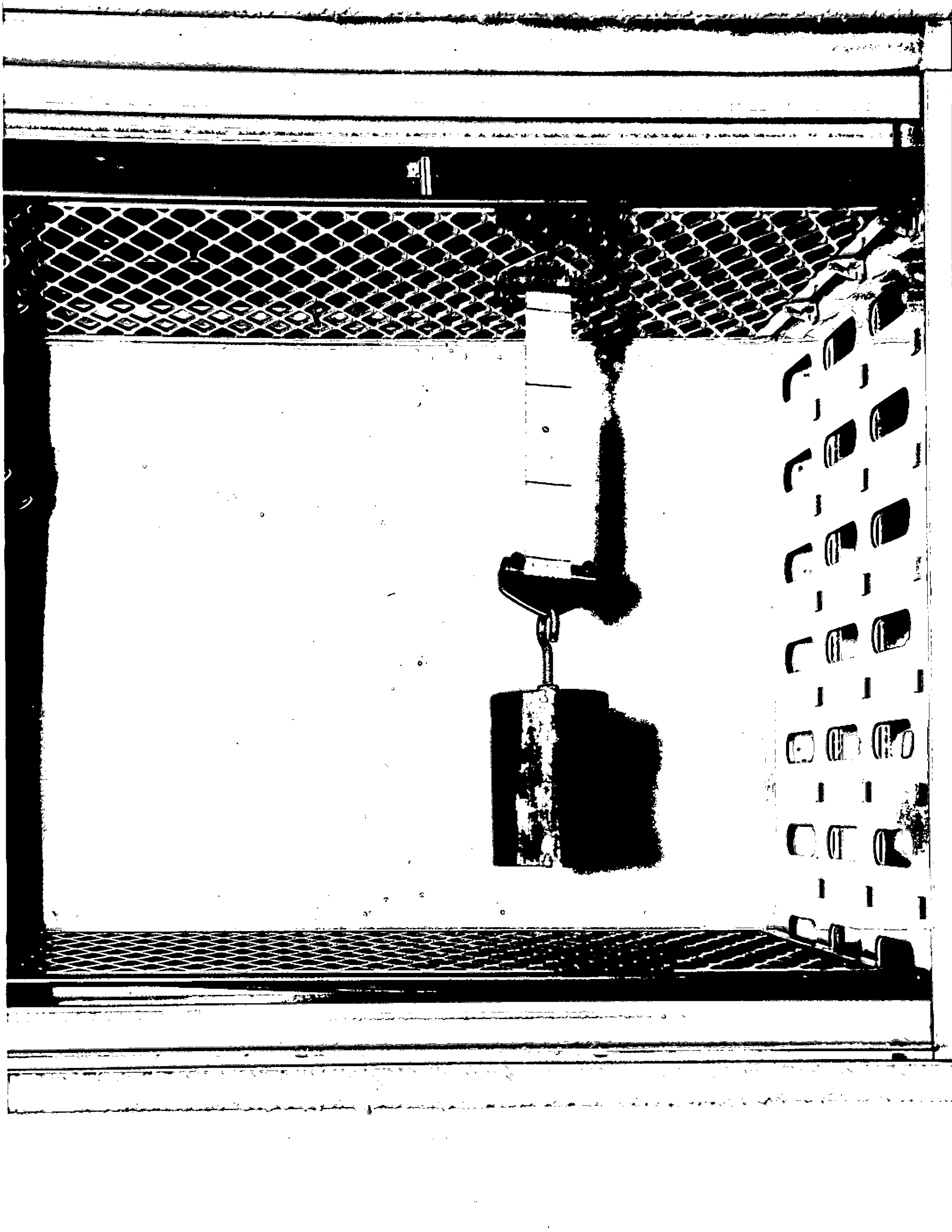
Test of five inch wide stitched samples sewn in the machine direction and pulled in the transverse direction with 20 stitches per inch. The threads tied at both ends before test.

Acrylic Coated Nylon

Sample No.	Strength of 5" Strip	Strength lb./in.
1	107.0	21.4
2	103.5	20.7
3	84.5	Broke at Jaw
4	97.0	19.4
5	121.5	24.3
6	99.5	19.9
Average		21.1

Mylar Laminated to Nylon

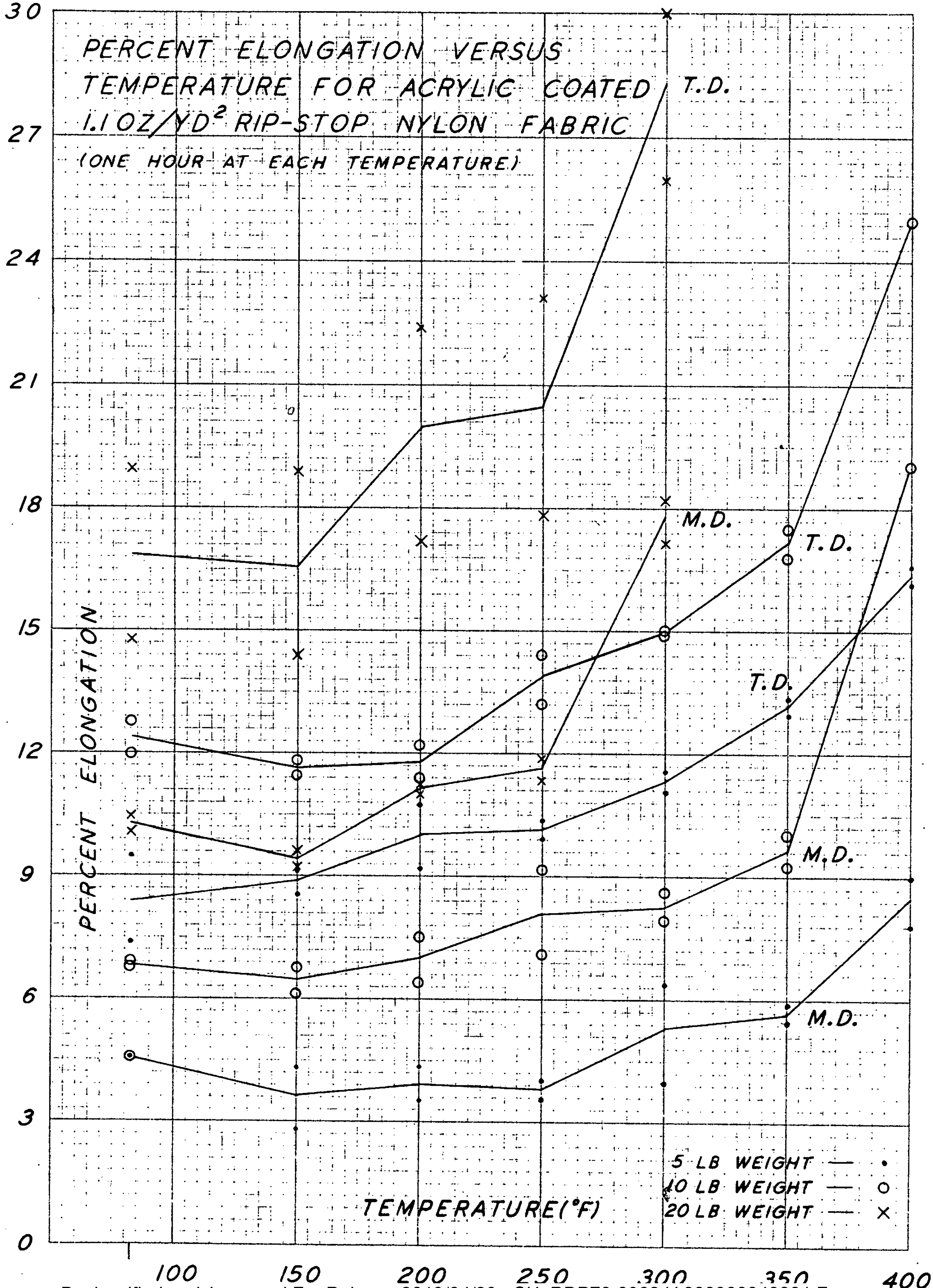
Sample No.	Strength of 5" Strip	Strength lb./in.
1	147.0	29.4
2	142.0	28.4
3	136.0	27.2
4	144.0	28.8
5	136.5	27.3
6	129.0	25.8
7	135.5	27.1
Average		27.7



Static Test in Oven

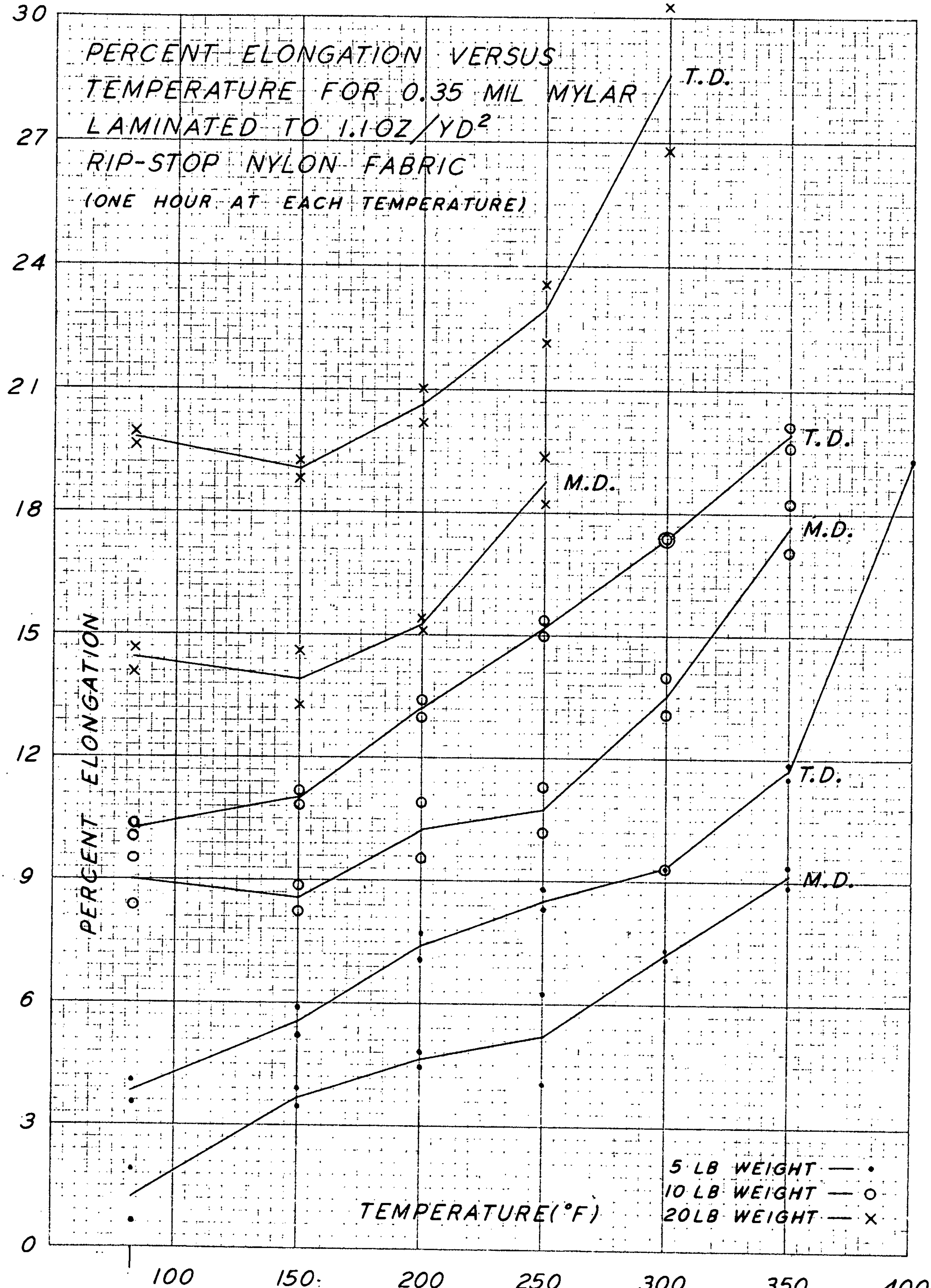
Appendix VI
Sheet E

 F


PERCENT ELONGATION VERSUS
TEMPERATURE FOR ACRYLIC COATED
1.1 OZ/YD² RIP-STOP NYLON FABRIC
(ONE HOUR AT EACH TEMPERATURE)
PERCENT ELONGATION
TEMPERATURE (°F)
T.D.
M.D.
T.D.
T.D.
M.D.
M.D.
5 LB WEIGHT — •
10 LB WEIGHT — O
20 LB WEIGHT — X
0
3
6
9
12
15
18
21
24
27
30
100
150
200
250
300
350
400
NO. 31.190-R. 10 DIVISIONS PER INCH BOTH WAYS. 70 BY 100 DIVISIONS.
CODEX BOOK COMPANY, INC. NORWOOD, MASSACHUSETTS.

UG62

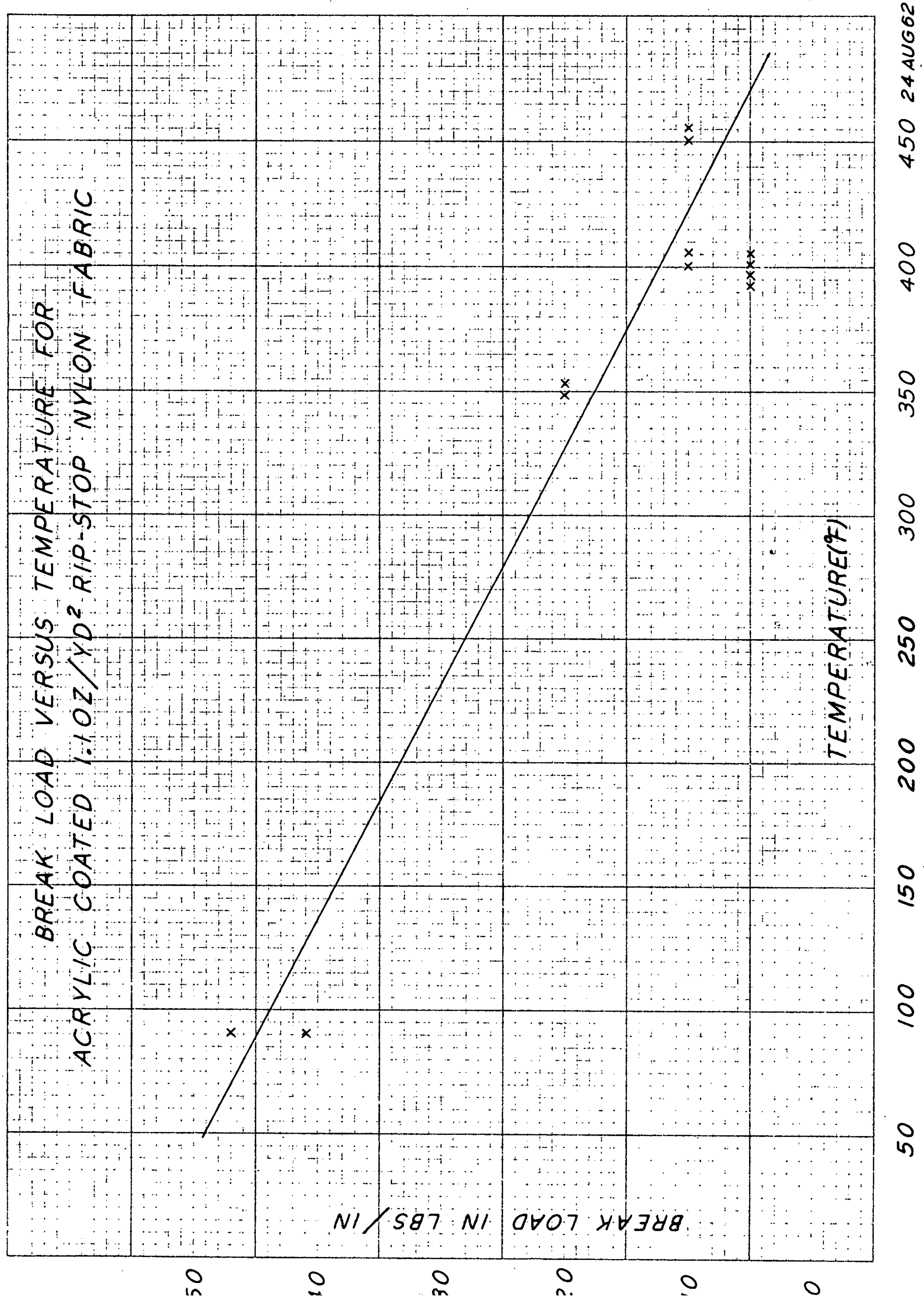
G

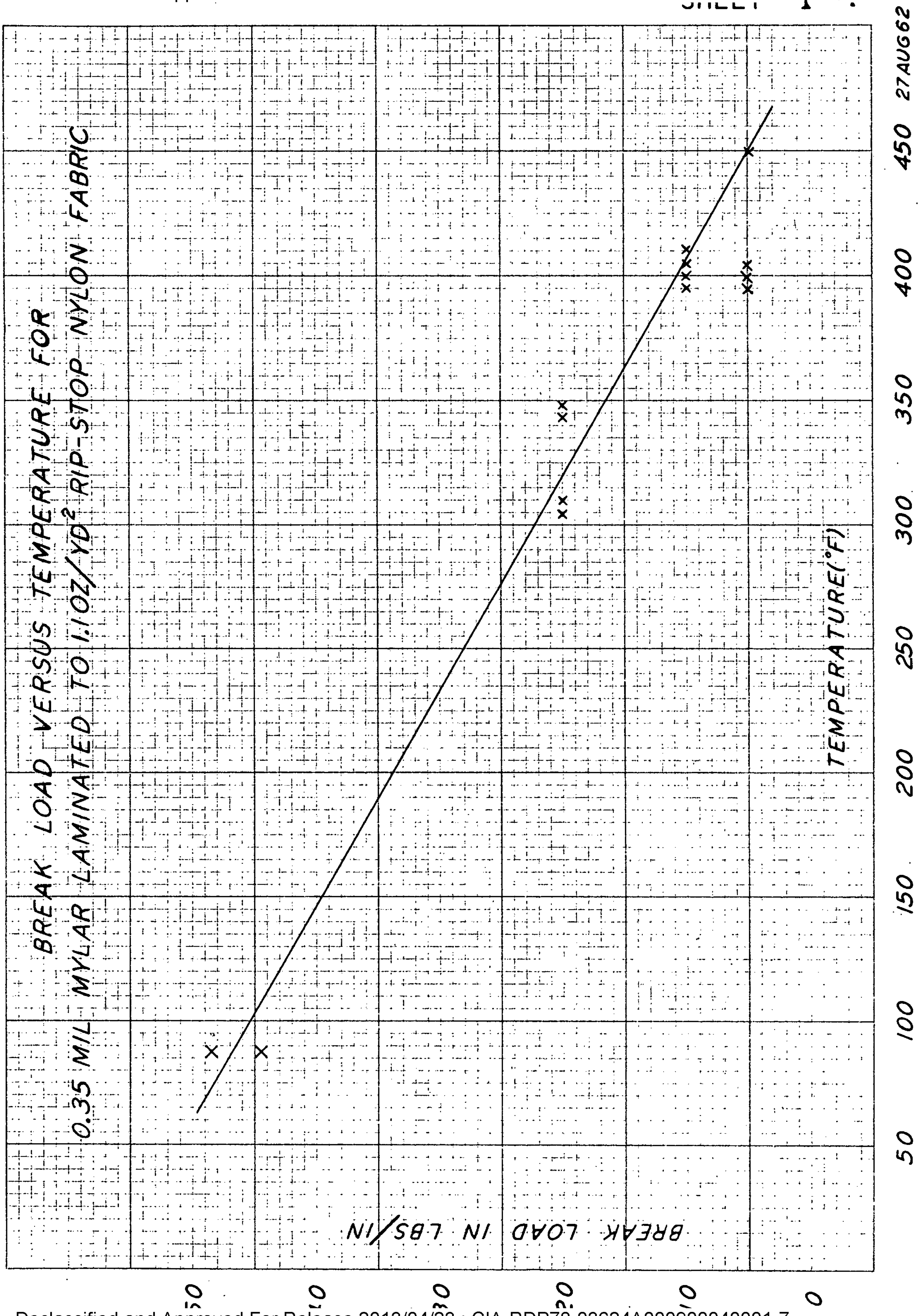


PERCENT ELONGATION VERSUS
TEMPERATURE FOR 0.35 MIL MYLAR
LAMINATED TO 1.1 OZ/YD²
RIP-STOP NYLON FABRIC
(ONE HOUR AT EACH TEMPERATURE)
PERCENT ELONGATION
TEMPERATURE (°F)
T.D.
M.D.
T.D.
M.D.
T.D.
M.D.
5 LB WEIGHT — •
10 LB WEIGHT — o
20 LB WEIGHT — x
0
3
6
9
12
15
18
21
24
27
30
100
150
200
250
300
350
400

1G62

SHEET H


24 AUG 62
BREAK LOAD VERSUS TEMPERATURE FOR
ACRYLIC COATED 1.1OZ/YD² RIP-STOP NYLON FABRIC
TEMPERATURE(°F)
BREAK LOAD IN LBS/IN
50
100
150
200
250
300
350
400
450
50
40
30
20
10
0


SHEET I
27AUG62
BREAK LOAD VERSUS TEMPERATURE FOR
0.35 MIL MYLAR LAMINATED TO 1.1OZ/YD² RIP-STOP NYLON FABRIC
TEMPERATURE(°F)
BREAK LOAD IN LBS/IN
50
100
150
200
250
300
350
400
450

Sheet J

Tear Strength in Pounds for Balloon Materials
Test Method - Tongue Method - A.S.T.M. D-39

Acrylic-coated 1.1 ounce per square yard rip-stop nylon fabric from Aldan Company

Sample No.	Machine Direction	Transverse Direction
1	2.9	3.3
2	2.9	3.4
3	2.8	3.5
4	2.9	3.8
5	2.9	3.7
Average	2.9 pounds	3.5 pounds

0.35 mil mylar laminated to 1.1 ounce per square yard rip-stop nylon fabric from Acme Backing Company

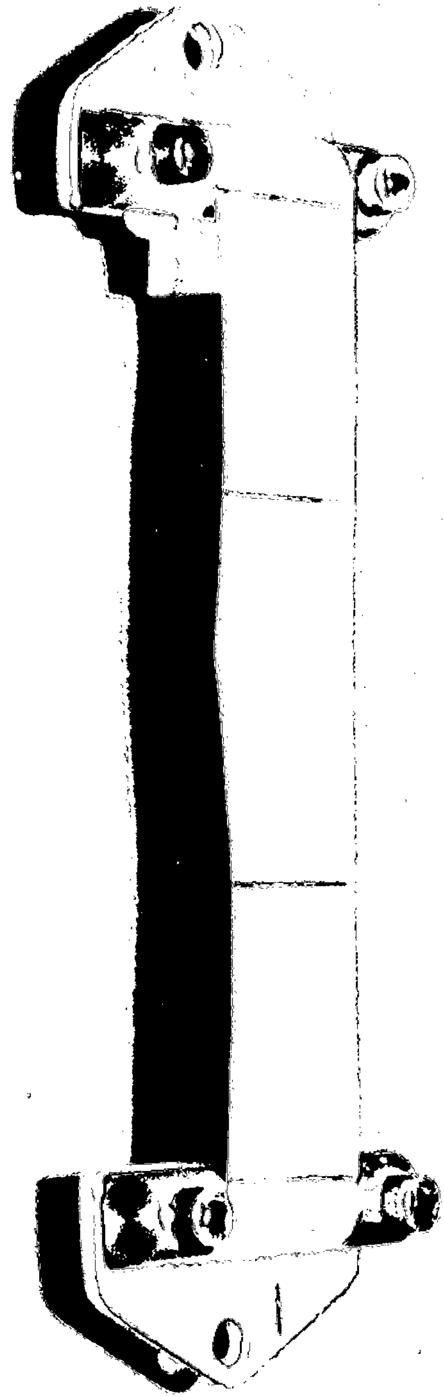
Sample No.	Machine Direction	Transverse Direction
1	3.9	3.2
2	3.7	3.5
3	3.8	3.4
4	3.7	3.6
5	3.7	3.6
Average	3.8 pounds	3.5 pounds

ANNEX I

Parts List

Clamp Assembly Aero Stat Material Testing

Quanity	1 2 3 4	
1	2B-1958	Clamp Ass'y.
	2B-1959	Plate Clamp
	2B-1960	Bar Clamp
	MS 35458-14	Cap Screw

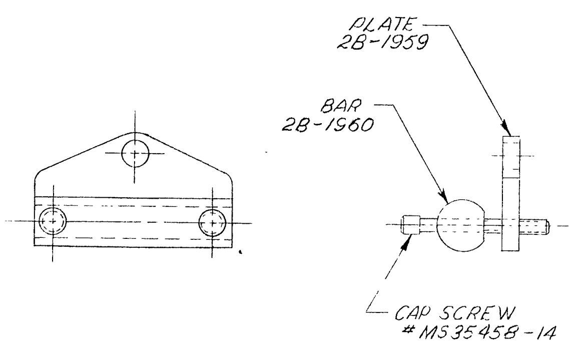


Installed Clamp

Appendix VI
Annex II

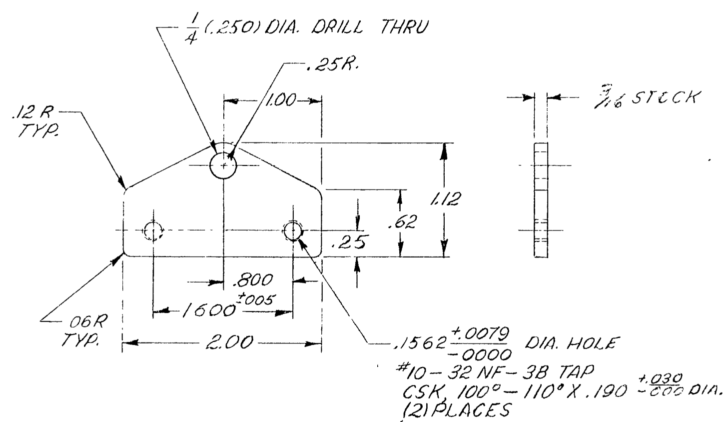
Declassified and Approved For Release 2013/04/23 : CIA-RDP78-03624A000900040001-7

2B-1958



		NEXT ASS'Y	USED ON
		APPLICATION	
MATERIAL 303 OR 304 STAINLESS STEEL	DATE 8-23-62	TITLE CLAMP ASSEMBLY- AERO STAT MAT'L TESTING	RAVEN industries, inc.
	DR C.L.G.		
UNLESS OTHERWISE SPECIFIED, TOLERANCES .XX ± .03 .XXX ± .010 BREAK EDGES .005-.025	CHK.		
	APPD		
	PKCV	SCALE FULL	DWG NO 2B-1958

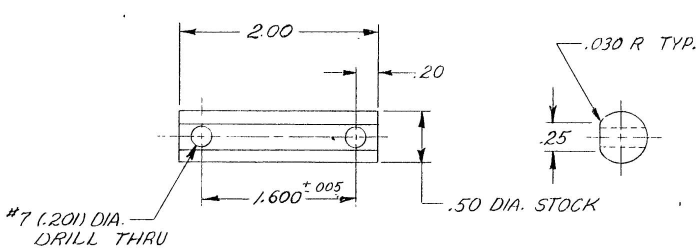
2B-1959



2B-1955	2B-1956
NEXT ASS'Y	USED ON
APPLICATION	

MATERIAL 303 OR 304 STAINLESS STEEL	DATE 8-30-61	TITLE PLATE, CLAMP	RAVEN industries, inc.
UNLESS OTHERWISE SPECIFIED: TOLERANCE .XX ± .03 .XXX ± .010 BREAK EDGES: .005-.015	DR C.L.G.		
	CHK [illegible]		
	APPD		DWG NO 2B-1959
	PROJ J.A. [illegible]	SCALE FULL	

2B-1960



2B-1958	2B-1958
NEXT ASS'Y	USED ON
APPLICATION	

MATERIAL 303 OR 304 STAINLESS STEEL	DATE 8-22-62	TITLE BAR, CLAMP	RAVEN industries, inc.
	DR C.L.G.		
UNLESS OTHERWISE SPECIFIED: TOLERANCE .XX ±.03 .XXX ±.010 BREAK EDGES .005-.025	CHK. [illegible]		
	APPD		DWG NO 2B-1960
	PROJ [illegible]	SCALE FULL	

11 October 1962

ANNEX III

Test Report

I. ADDITIONAL TESTS OF HOT AIR BALLOON FABRIC

Additional tests were made on acrylic coated 1.1 ounce per square yard rip-stop nylon fabric from Aldan Company and 0.35 mil mylar laminated to 1.1 ounce per square yard rip-stop nylon fabric from Acme Backing Company. The original tests were reported in Technical Note #30.

This series of tests were made to determine the effect of high temperature oven aging on hot air balloon fabric. Since our original tests had shown the acrylic coated nylon to be an acceptable material with less weight, it was chosen as the material to use for this aging test. 250°F was chosen as the aging temperature, since this is above the temperature we would expect as a maximum operating temperature for a hot air balloon.

II. AGING TEST PROCEDURE

The temperature controlled oven was set at 250°F. Six samples of acrylic coated nylon were cut 1 7/8" wide and 20" long. The samples were laid on the floor of the oven and removed after exposures of 24, 48, 72, 96, 168 and 240 hours.

III. TEST RESULTS

The tests showed only small changes in color after 240 hours with no apparent increase in porosity or change in fabric flexibility.

Two tensile test of each aged sample were pulled in the transverse direction. The new acrylic coated material had an average tensile strength in the transverse direction of 41.7 pounds per inch of width with No. 2B1958 1/2" round clamps. The average tensile strengths found for the aged samples with 2B1958 clamps are shown on Sheet A. This shows that the material retains approximately 50% of its strength after 240 hours at 250°F. I feel that this acrylic coated nylon should be used in hot air balloons with the caution that panels that show any color change should be replaced. This would give a material that has a strength of at least 25 pounds per inch.

A brief test was also run to measure the self-adhesion of the two fabrics. To do this pieces of the material were gathered and tied with cord and placed in the oven at 250°F for 16 hours. The samples were cooled to room temperatures and the cord removed. Both materials showed only minor self-adhesion, but the wrinkles were relatively permanent. This test indicates that the tied top of a hot air balloon would open up very easily when the line that holds it closed is cut.

The samples of balloon fabric that were checked for self-adhesion were also tested for tear strength. Sheet B shows the results of the tear tests. Because we had a smaller sample of the acrylic coated material we ran fewer tear tests. With the small number of samples of aged materials, these numbers are not absolute, but it appears that the aging of the materials for 16 hours at 250°F did not change the tear strength.

IV. SUMMARY

This series of tests shows that the acrylic coated nylon retains about 50% of its new strength after long term aging at 250°F. Also the acrylic coated nylon and the mylar laminated nylon do not exhibit enough self-adhesion to keep the top closed after the tie line is cut. Since this acrylic coated material shows some fading in color with high temperatures, this can be a safety feature. Any area of a balloon envelope that is discolored should be replaced. If the fabric is bright in color the material is in nearly original condition and should be near to full strength.

In my opinion the acrylic coated 1.1 ounce per square yard rip-stop nylon from Aldan Company is a very good material. This material should make

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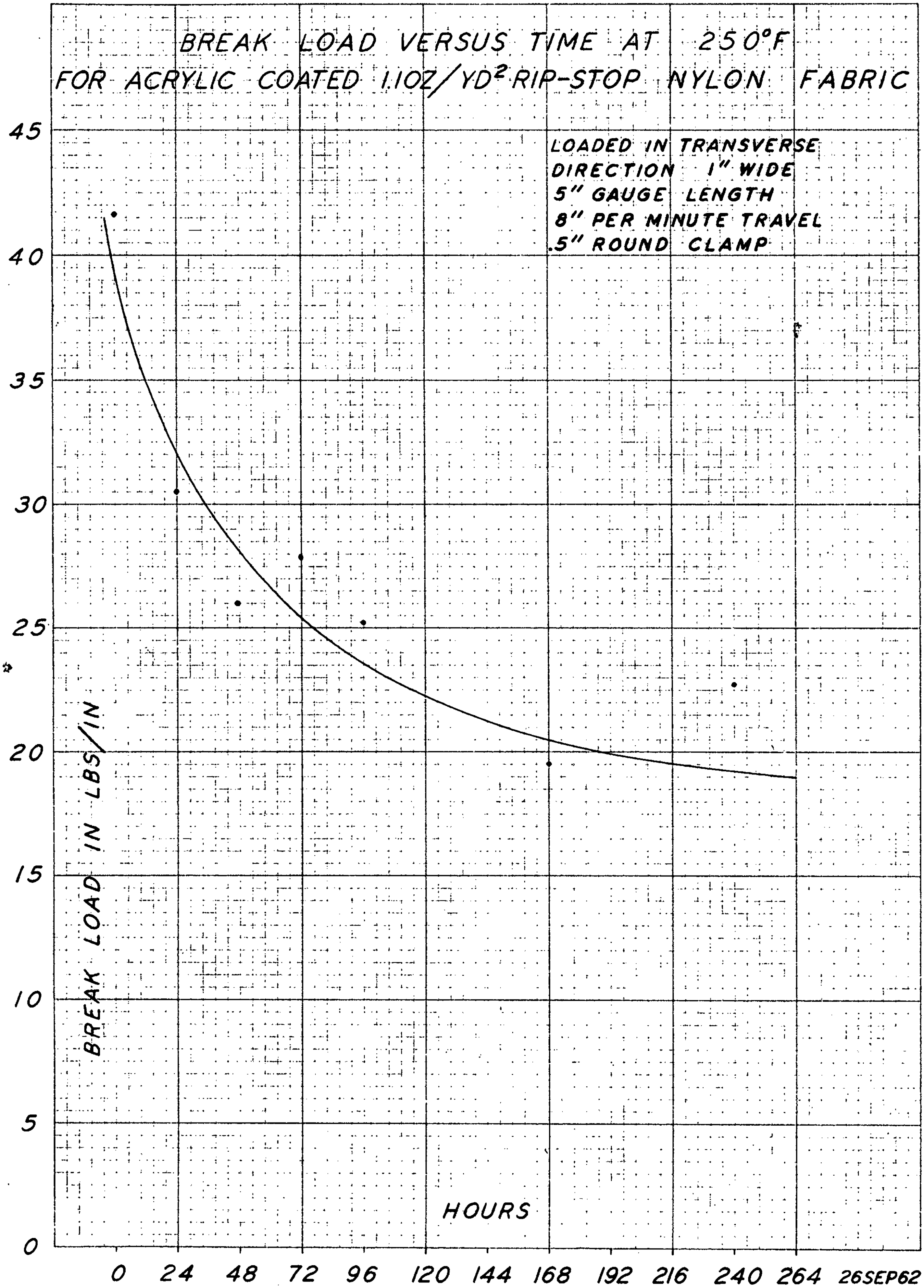
a good balloon fabric for our hot air balloon program.


BREAK LOAD VERSUS TIME AT 250°F
FOR ACRYLIC COATED 1.1OZ/YD² RIP-STOP NYLON FABRIC
LOADED IN TRANSVERSE DIRECTION 1" WIDE
5" GAUGE LENGTH
8" PER MINUTE TRAVEL
.5" ROUND CLAMP
BREAK LOAD IN LBS/IN
HOURS
0
5
10
15
20
25
30
35
40
45
0 24 48 72 96 120 144 168 192 216 240 264
26SEP62

TEAR STRENGTH IN POUNDS FOR BALLOON MATERIALS

Materials aged 16 hours at 250°F

Test Method: Tongue Method, A.S.T.M. D-39

Acrylic coated 1.1 ounce per square yard rip-stop nylon fabric from Aldan Company.

	Machine Direction	Transverse Direction
Average New	2.9	3.5
Aged Samples		
1.	3.9	
2.	3.7	
Average	3.8	

0.35 mil mylar laminated to 1.1 ounce per square yard rip-stop nylon fabric from Acme Backing Company

	Machine Direction	Transverse Direction
Average New	3.8	3.5
Aged Samples		
1.	2.9	3.9
2.	2.5	3.7
3.	3.2	3.1
Average	2.9	3.6

Appendix VII

Appendix VII

A Summary of Hot Air Balloon Technical Data

Report No. 34

25 October 1963

J. R. Smith

Raven Industries, Inc.
Sioux Falls, South Dakota

Area Code 605, Telephone 336-2750 Post Office Box 916

Declassified and Approved For Release 2013/04/23 : CIA-RDP78-03624A000900040001-7

In 1783 men first left the earth in a flying machine - a hot air balloon. The early Montgolfier systems were used for scientific exploration of the atmosphere, for military observation posts, for the evacuation of Paris in 1873, and for a wide variety of load and personnel transport systems.

In the mid-1950's interest was renewed in the hot air balloon. The availability of new materials, new design concepts and sophisticated heat supply systems has made it possible to build modern Montgolfier balloons with greatly extended performance characteristics. Since 1960, Raven Industries, Inc. has been engaged in the development of such systems. Specific applications under study include:

Manned observation platforms

Flare support systems

Heavy load transport

Re-entry vehicle recovery

The most important characteristics of these balloons is the inclusion of a burner system carried on board, together with a fuel supply and controls to regulate burning rate. By increasing the temperature of the heated air, the balloon will be made to rise. When a descent is desired, the heat is turned down. By using liquid fuels, straightforward modulation of the fuel supply can be accomplished with the result that systems may be operated by instruments and radio controls, as well as by a pilot.

This paper will present some of the theoretical performance data on which systems may be designed.

At sea level, air heated to 191^{O}F above the standard temperature of 59^{O}F will have a buoyancy of 21 lbs. per thousand cubic feet. This increases to 31 lbs. if the air is heated to 400^{O}F (341^{O} superheat), but most of those skin materials which are readily available and easy to fabricate will degrade if held at temperatures of 300 to 400^{O}F for long periods of time. Accordingly, Figure 1 has been prepared to show the lift derived as a function of altitude when the average temperature of the heated air is 250^{O}F. In this calculation, a standard ARDC temperature distribution has been assumed. Figure 2 illustrates tests which have been run to relate the average temperature of the hot air to the balloon skin temperature. Fortuitously, the hottest skin temperature (at the crown) is just about equal to the average temperature of the heated air.

The specific lift derived from the hot air is used in supporting the balloon envelope itself, rigging and controls, a payload container, an in-flight burner, a fuel supply and payload. If flight duration is increased, the fuel consumption goes up, and the usable payload weight with a given balloon is reduced. Likewise, more fuel is required to support a given gross load at a higher altitude. In order properly to design a system, the following parameters must be considered:

payload to be supported

altitude desired

duration.

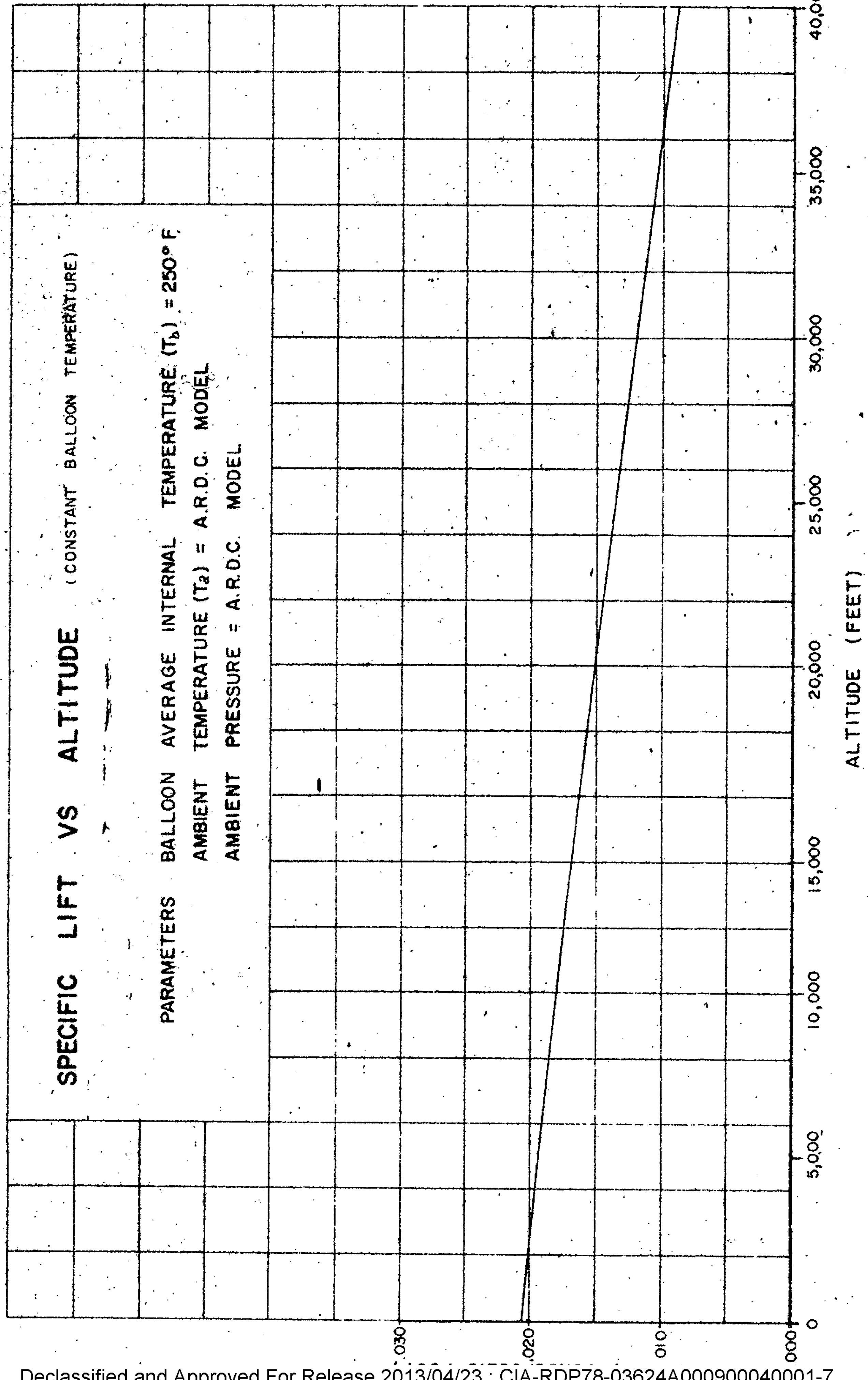
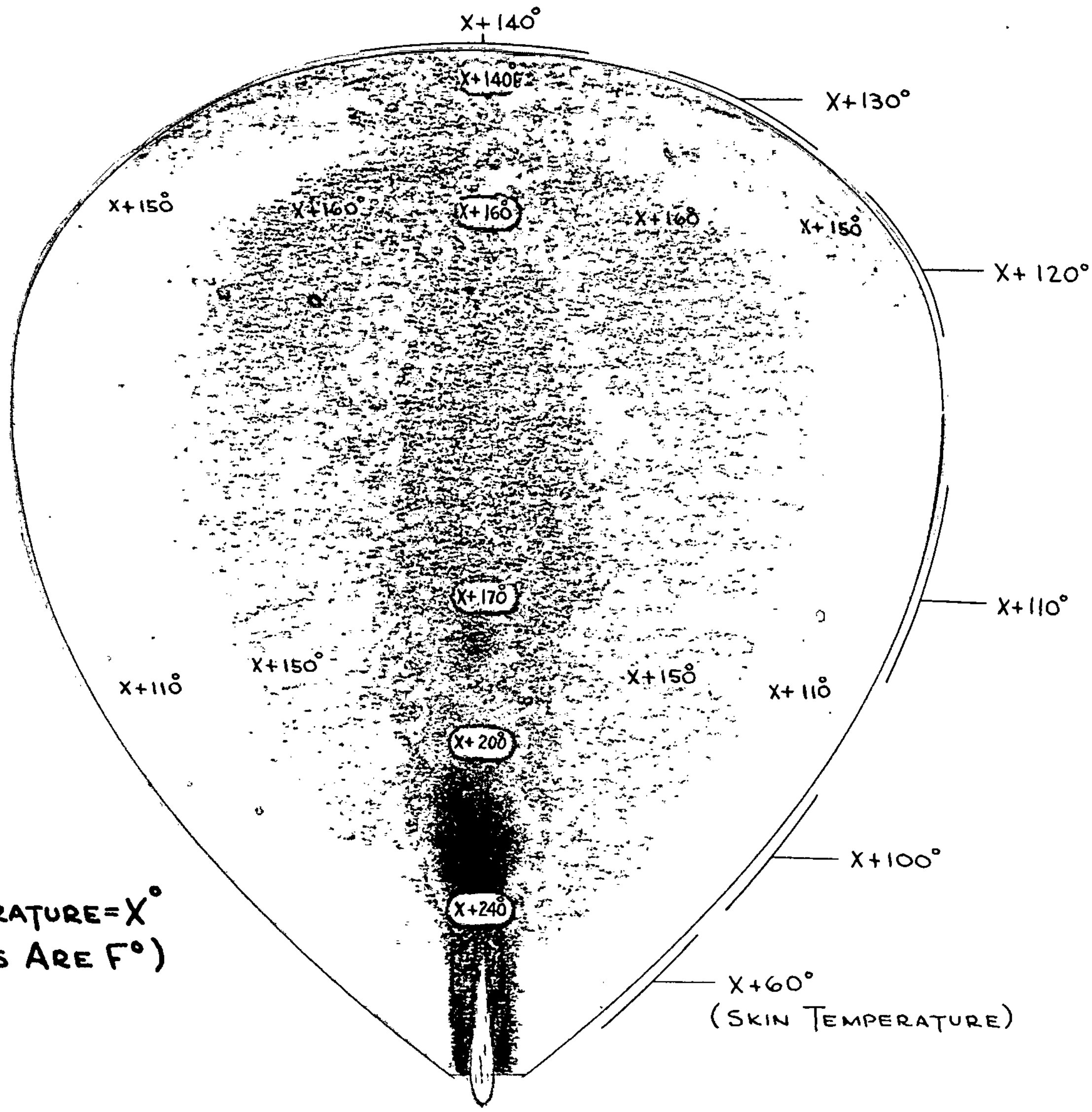

SPECIFIC LIFT VS ALTITUDE
(CONSTANT BALLOON TEMPERATURE)
PARAMETERS
BALLOON AVERAGE INTERNAL TEMPERATURE (T_b) = 250° F
AMBIENT TEMPERATURE (T_a) = A.R.D.C. MODEL
AMBIENT PRESSURE = A.R.D.C. MODEL
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
ALTITUDE (FEET)
.030
.020
.010
.000

FIGURE 1

Apex Temperature Is Approximately Equal To The Average Temperature Differential



Ambient Temperature=X°
(All Temperatures Are F°)

Average Temperature Differential In This Illustration Is 140°F

Internal And Skin Temperature Profile As Determined By Model Hot Air Balloon Experiments

Figure 2

Figures 3 - 5 may be used as approximate guides to system specification. Figure 3 relates balloon diameter to gross lift. Gross lift must include the balloon weight, and the tankage and fuel weight; these weights may be taken from Figures 4 and 5. The synthesis of these weight considerations is represented on Figure 6 where, by using a number of simplifying assumptions, balloon diameter is related to payload capacity at 10,000 feet. Thus, a balloon 25 feet in diameter can carry a payload of 60 lbs. for one hour. (From Figure 5, it may be seen that a 25 foot hot air balloon will need about 30 lbs. of fuel and tankage for each hour of flight. Thus, the payload becomes 30 lbs. if two hours of floating is desired.)

Again, from Figure 6, the payload carried by a 50 foot balloon is seen to be 900 lbs., while a 100 foot vehicle can support 8,700 lbs., and a 250 foot model is capable of supporting a payload of some 170,000 lbs. for one hour. (Fuel needed is less than 1,500 lbs. per hour of flight.)

It should be stated that these extremely high lifts have not yet been physically demonstrated. Computations have been made, based on existing materials and standard design data. All of the performance estimates made in these figures are well within the working limits of existing materials.

Fuel supply systems, controls, ground handling techniques and ground support equipment have been considered for a wide range of applications.

GROSS LIFT VS BALLOON DIAMETER

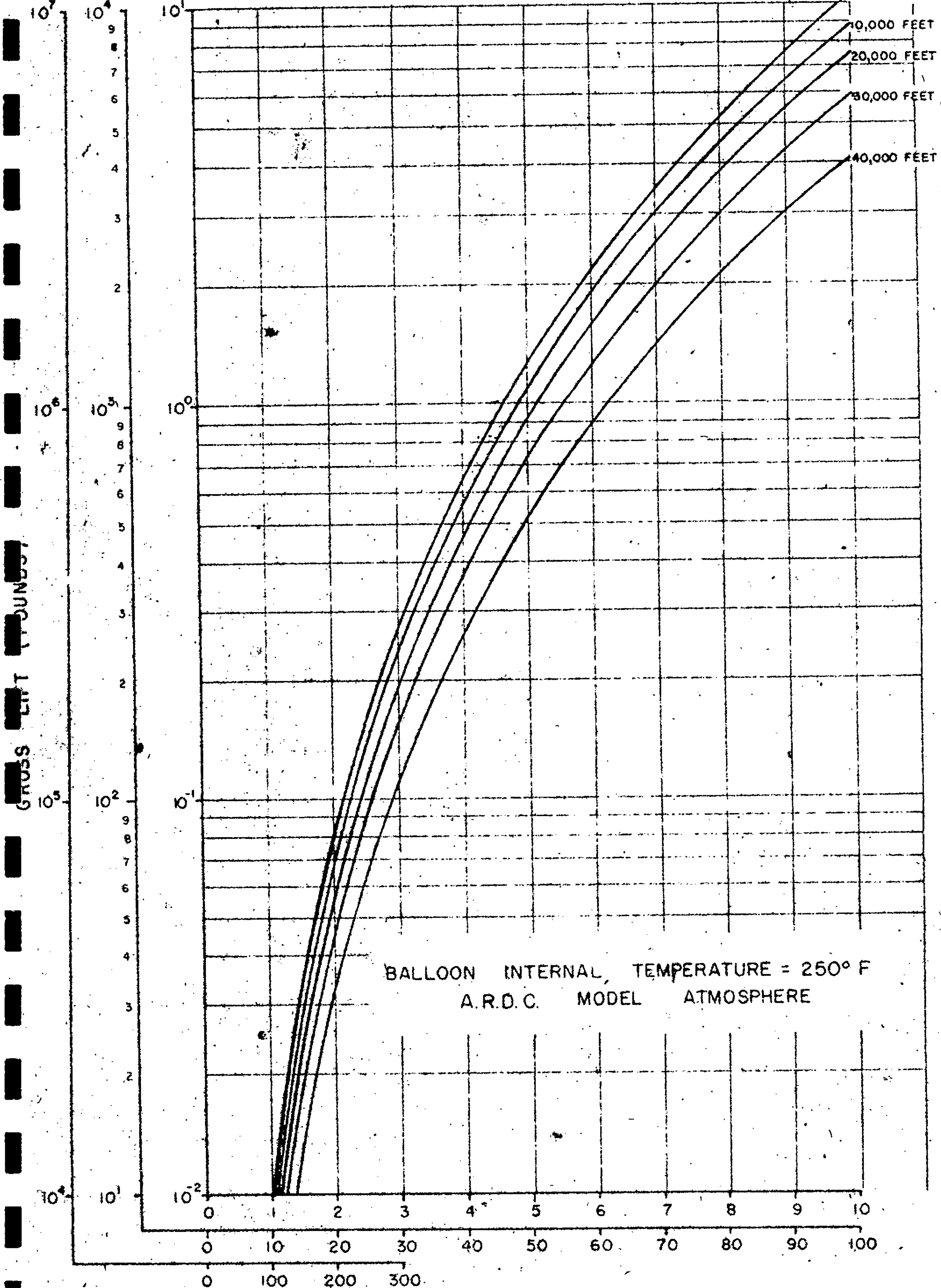


FIGURE 3

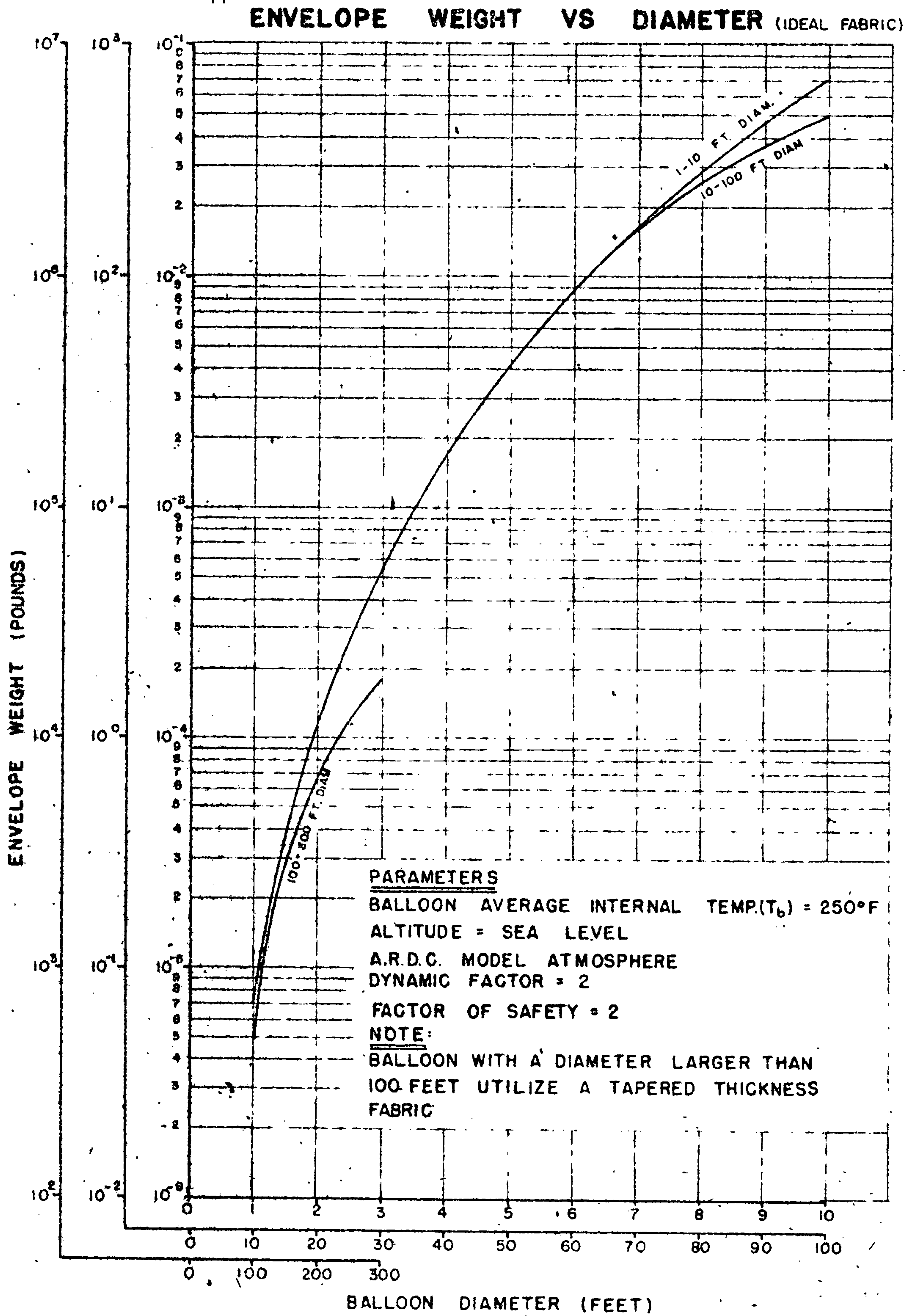
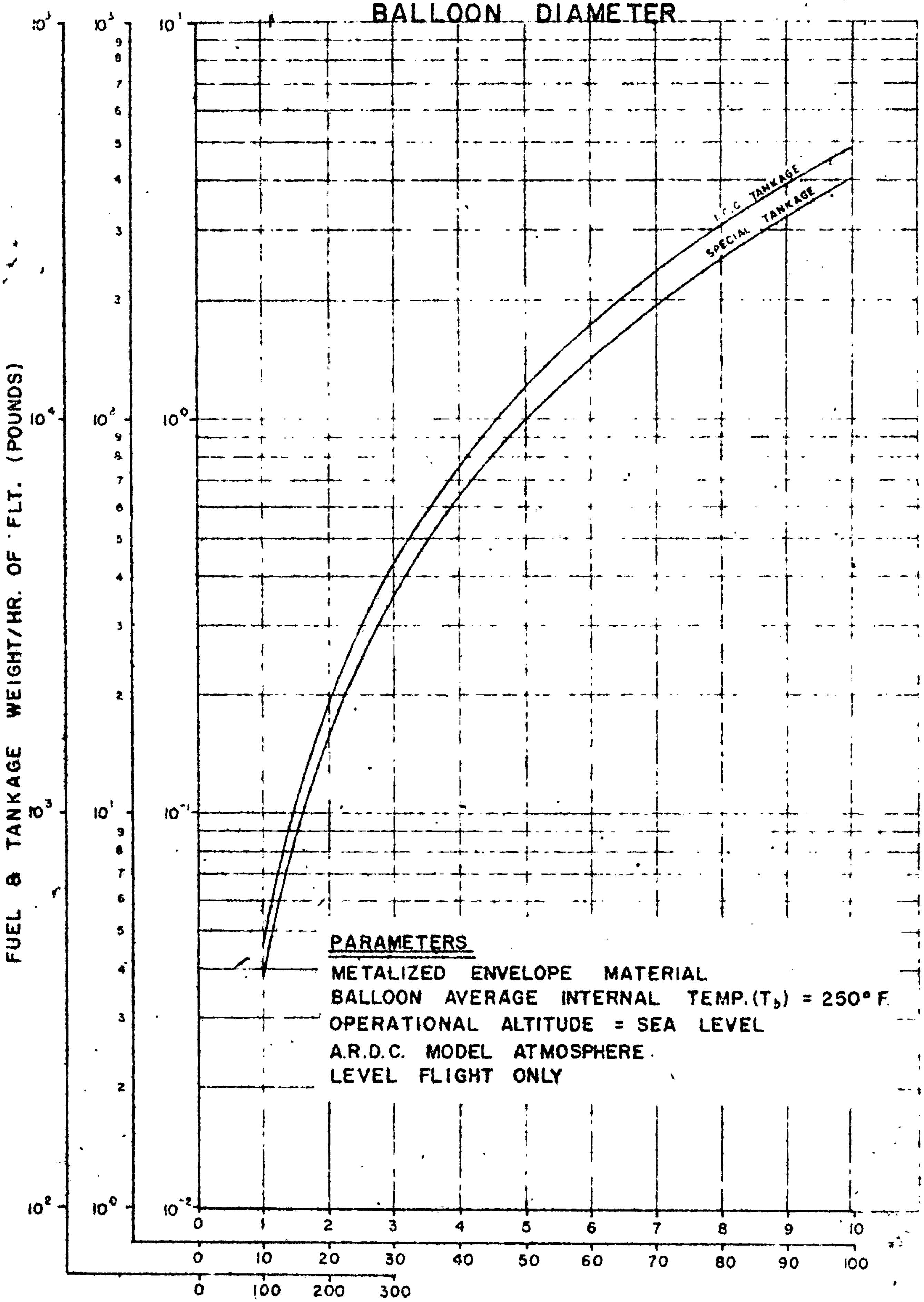

ENVELOPE WEIGHT VS DIAMETER (IDEAL FABRIC)
ENVELOPE WEIGHT (POUNDS)
BALLOON DIAMETER (FEET)
1-10 FT. DIAM.
10-100 FT. DIAM
100-300 FT. DIAM
PARAMETERS
BALLOON AVERAGE INTERNAL TEMP.(T_b) = 250°F
ALTITUDE = SEA LEVEL
A.R.D.C. MODEL ATMOSPHERE
DYNAMIC FACTOR = 2
FACTOR OF SAFETY = 2
NOTE:
BALLOON WITH A DIAMETER LARGER THAN 100 FEET UTILIZE A TAPERED THICKNESS FABRIC

FIGURE 4

FUEL & TANKAGE WEIGHT
PER HOUR OF FLIGHT
VS
BALLOON DIAMETER



PAYLOAD VS DIAMETER
(AT 10,000 FEET)

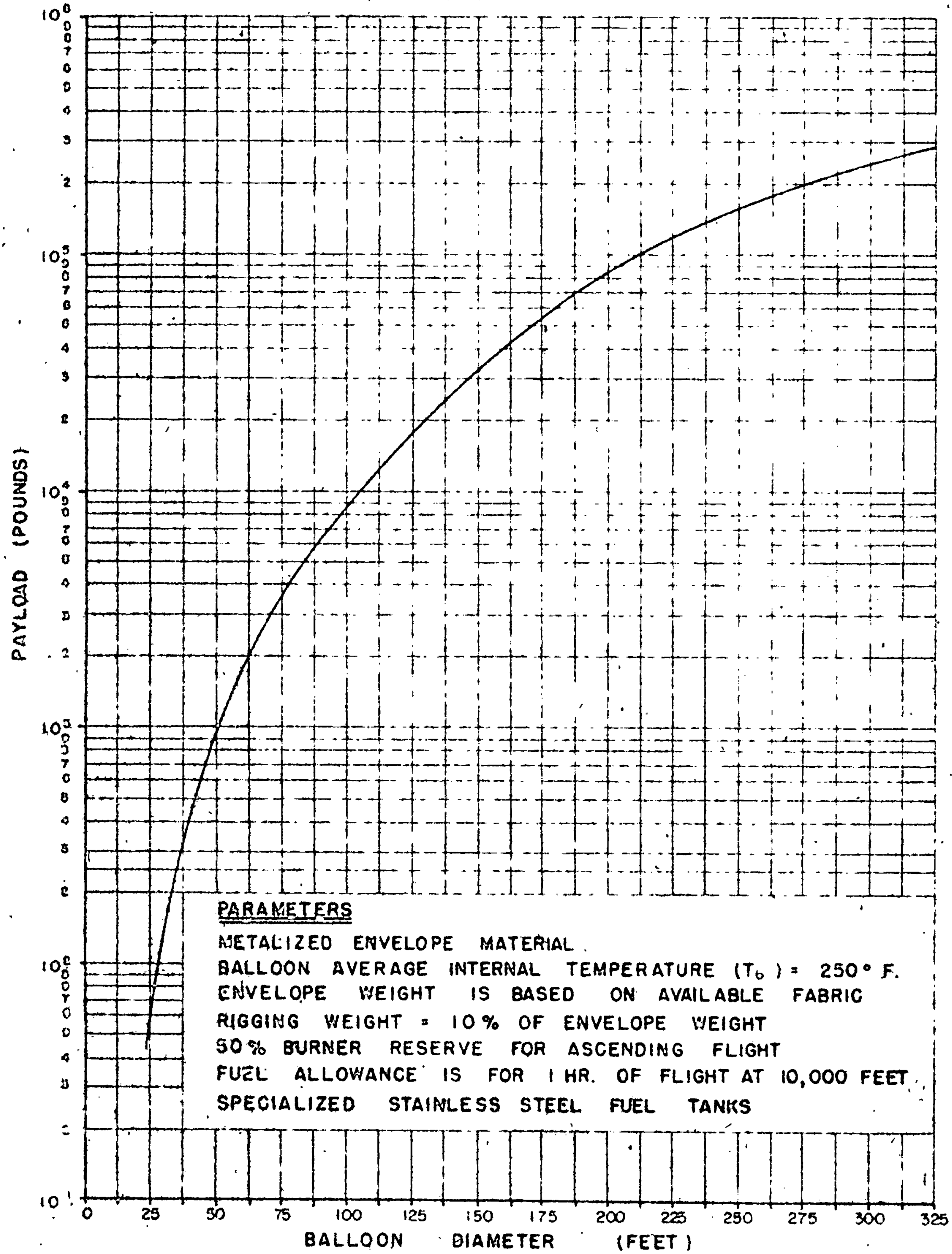


FIGURE 6

There appear to be no insurmountable problems. Indeed, the ease of handling, the low cost of operations, and the simple logistics militate toward the use of these hot air systems whenever a repeated or prolonged lifting task is involved.

Special applications involve the mid-air inflation of a hot air system. The system may be packaged to a relatively small volume, deployed, filled with ram air which is then heated to sustain flight. This technique has been successfully demonstrated.

Figures 7 and 8 show the packed volume and the package weight of the system as a function of balloon diameter. Figure 8 includes fuel allowance for level flight for one hour, at various altitudes, Figure 9 shows the amount of heat, in Btu's, needed initially to bring the system to equilibrium. This heat may be supplied by the liquid fuel used for sustaining flight, or it may be obtained from solid pyrotechnic charges or other sources. Using a hydrocarbon fuel such as propane, JP-1 or gasoline, one pound of fuel will produce some 21,500 Btu's.

Figures 10 and 11 show existing hot air systems in use (50-foot manned transport and flare support system). Figure 12 is a projected hot air blimp, now under design study, and Figure 13 illustrates the mid-air re-entry vehicle recovery concept.

Specific details of these and other programs will be provided upon request.

VS DIAMETER

(IDEAL FABRIC)

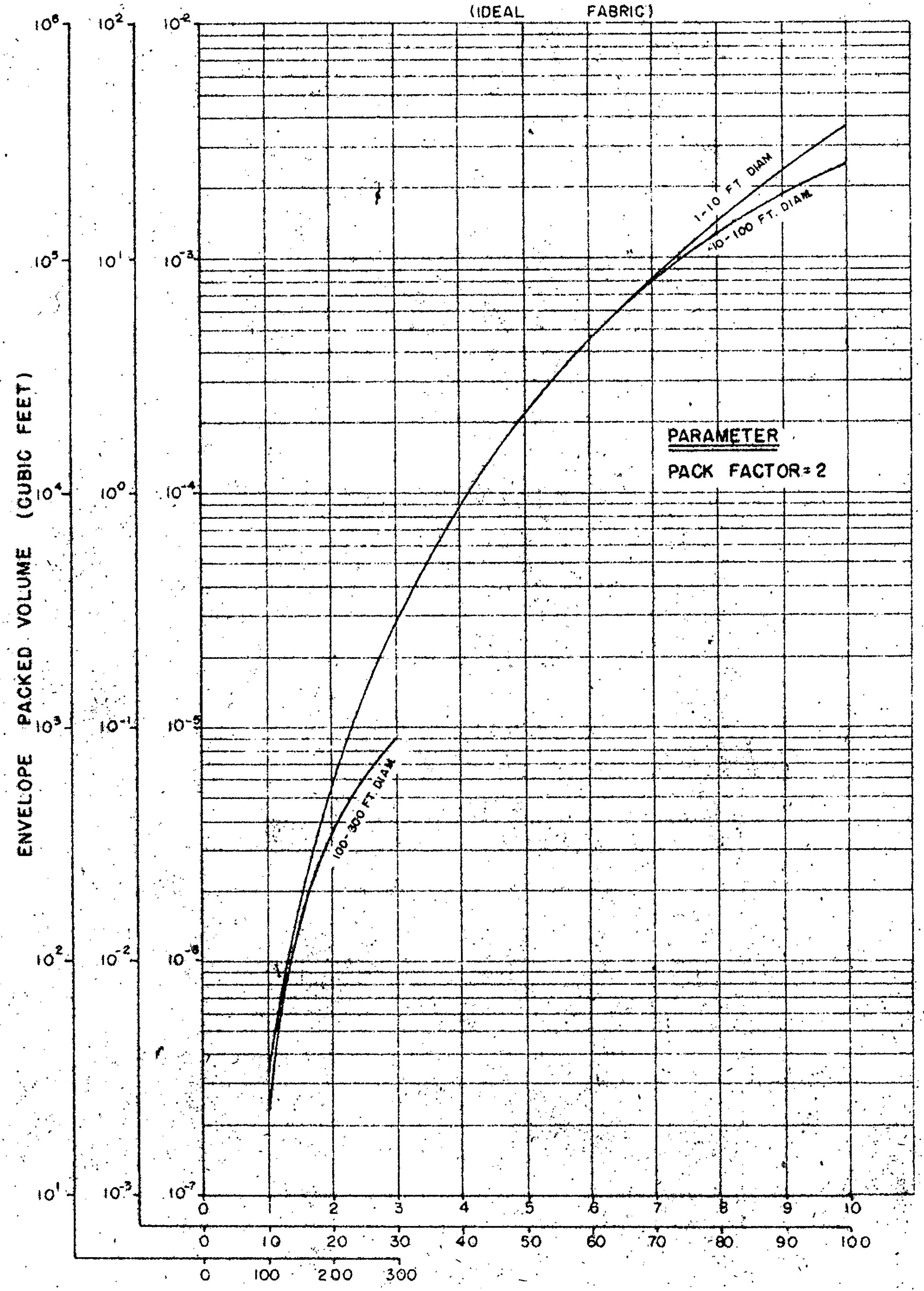
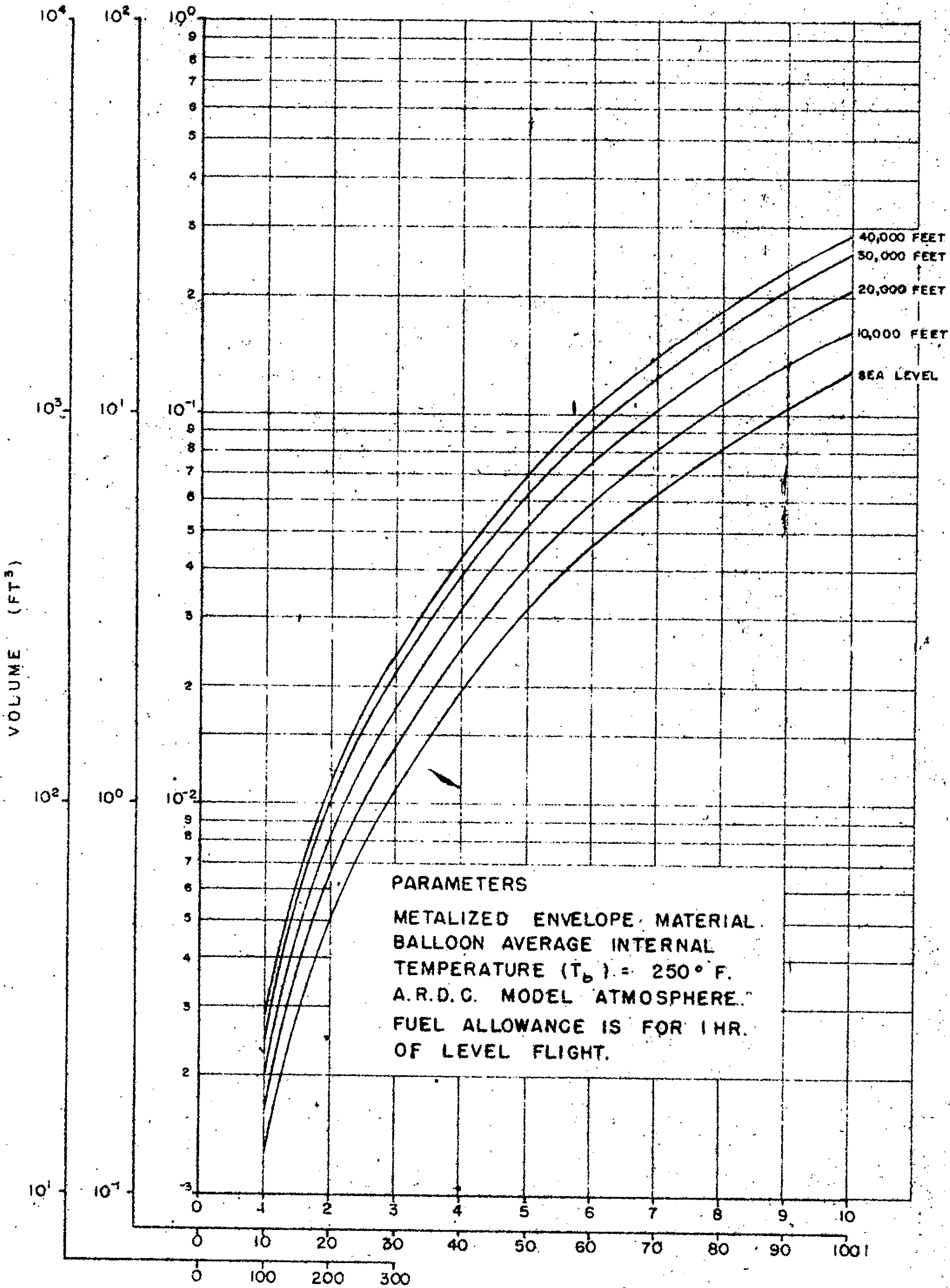


 FIGURE 7

VS
BALLOON DIAMETER



GURE 8

VS
BALLOON DIAMETER

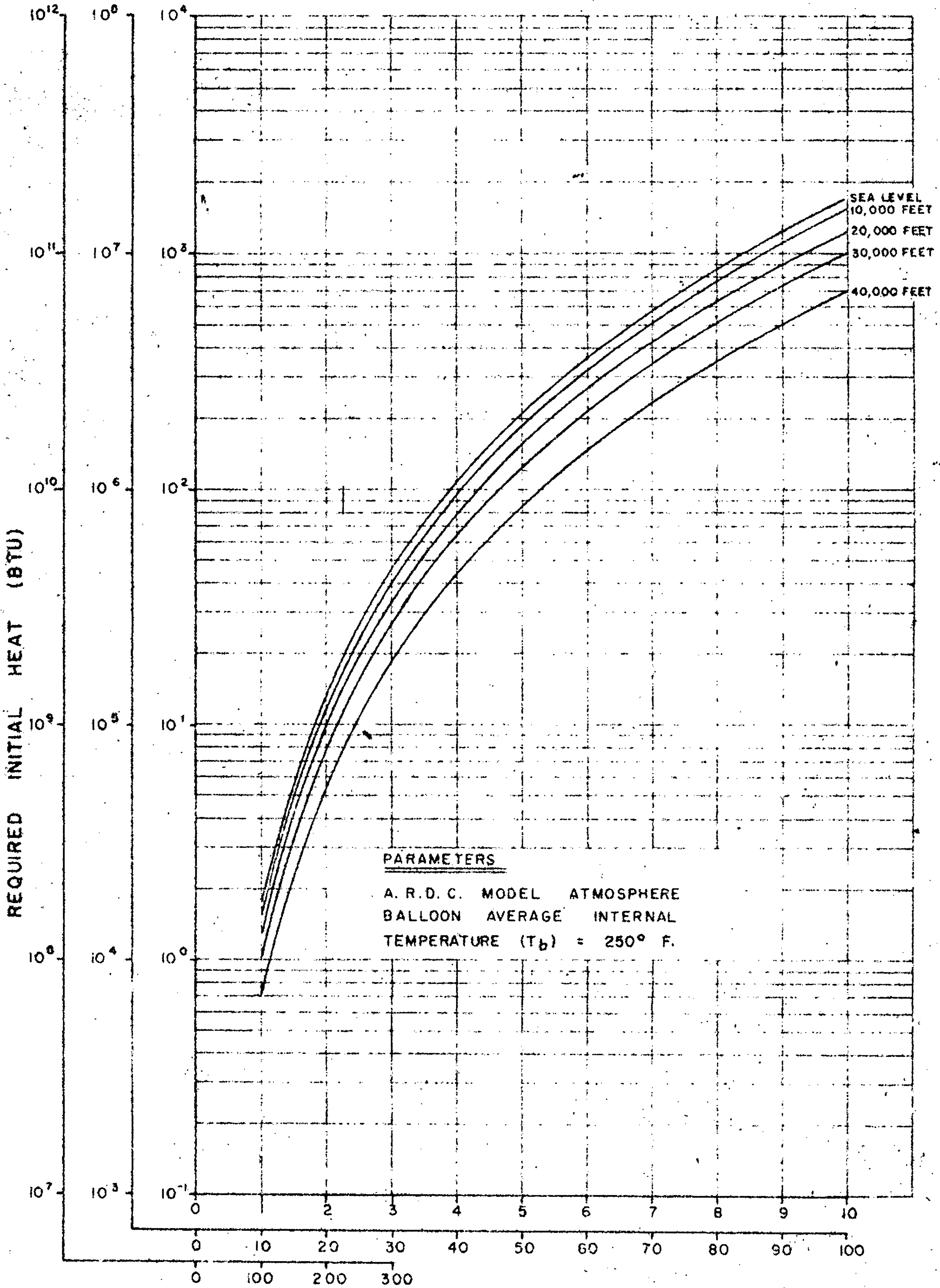


Figure 10

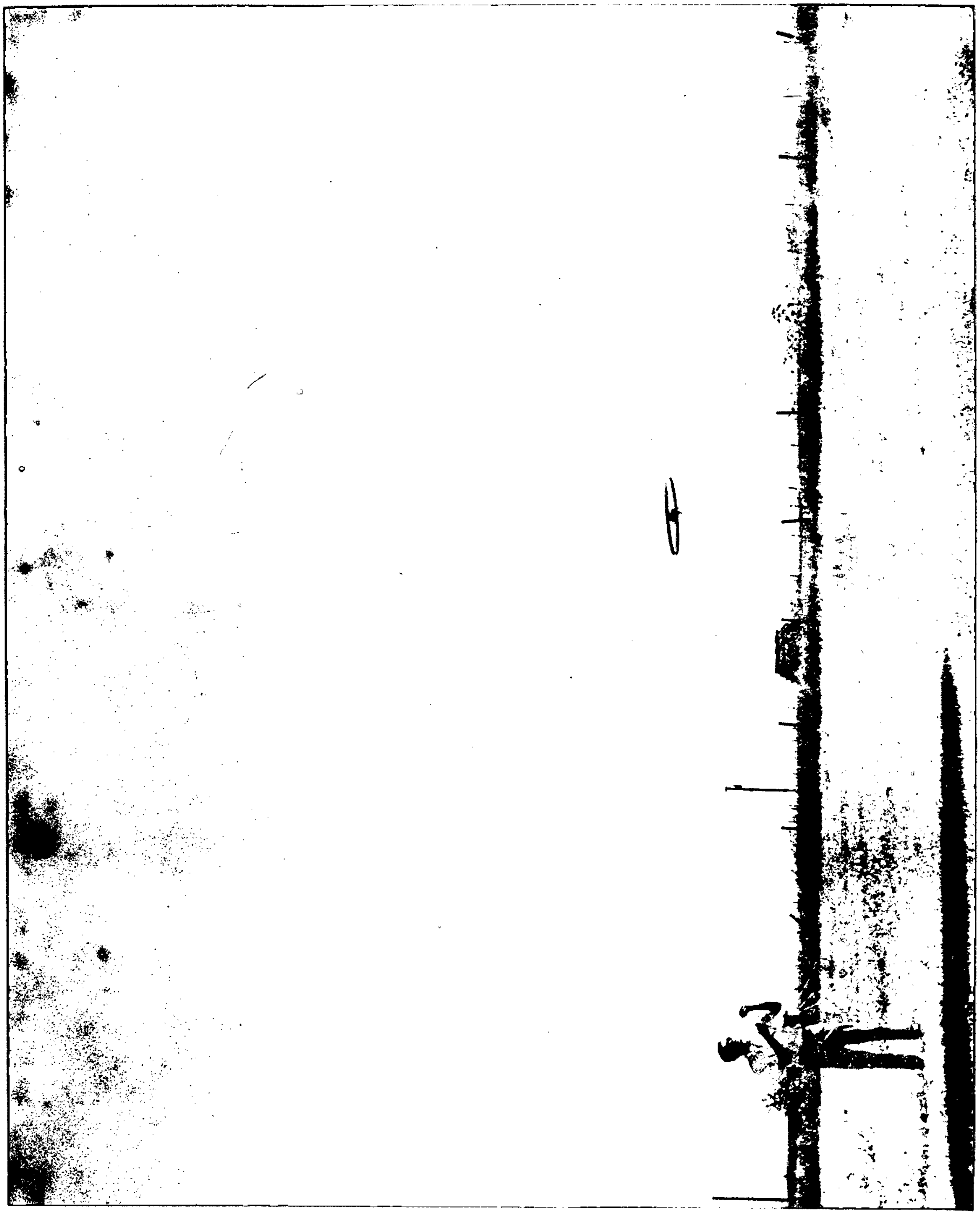


Figure 11

VULCRAFT

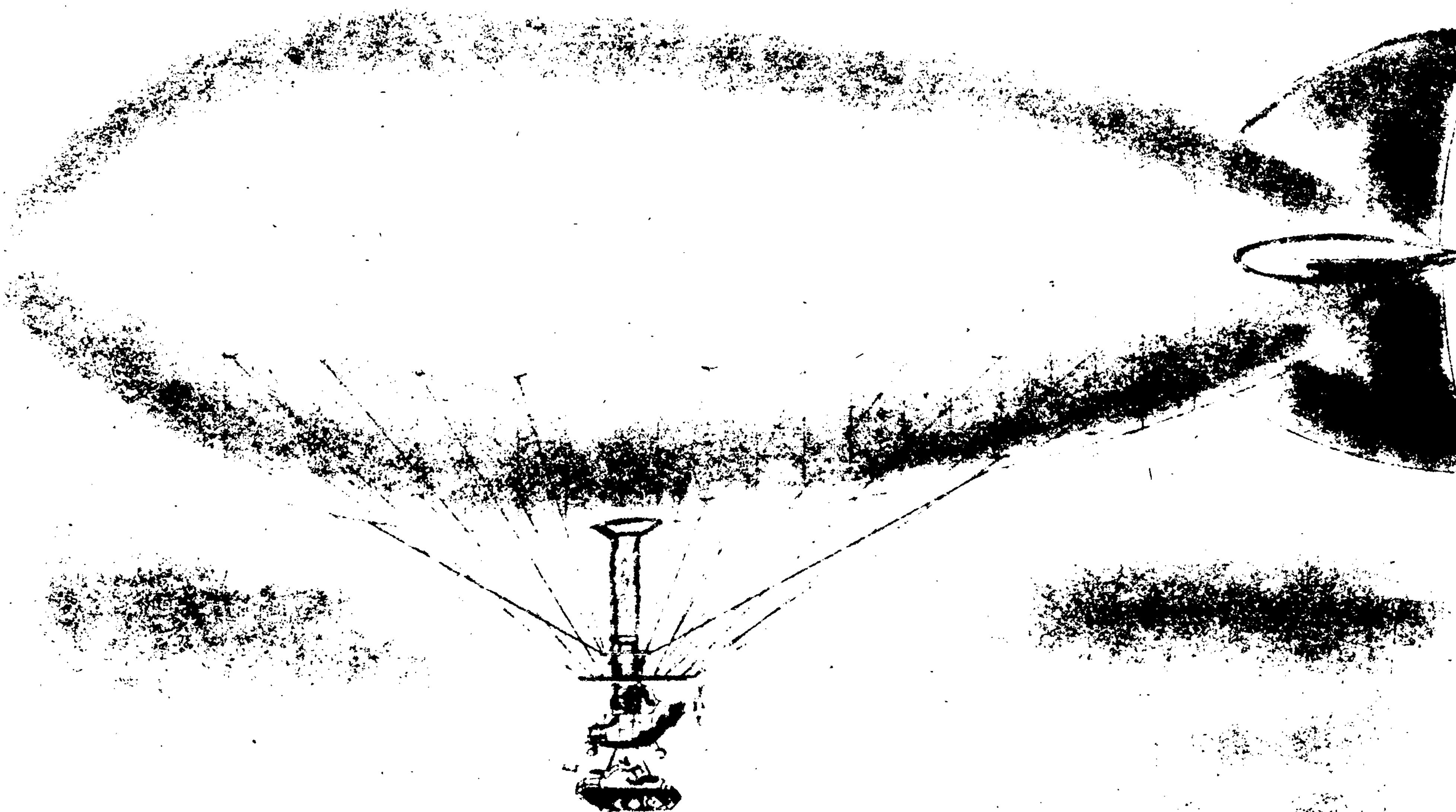


FIGURE 12

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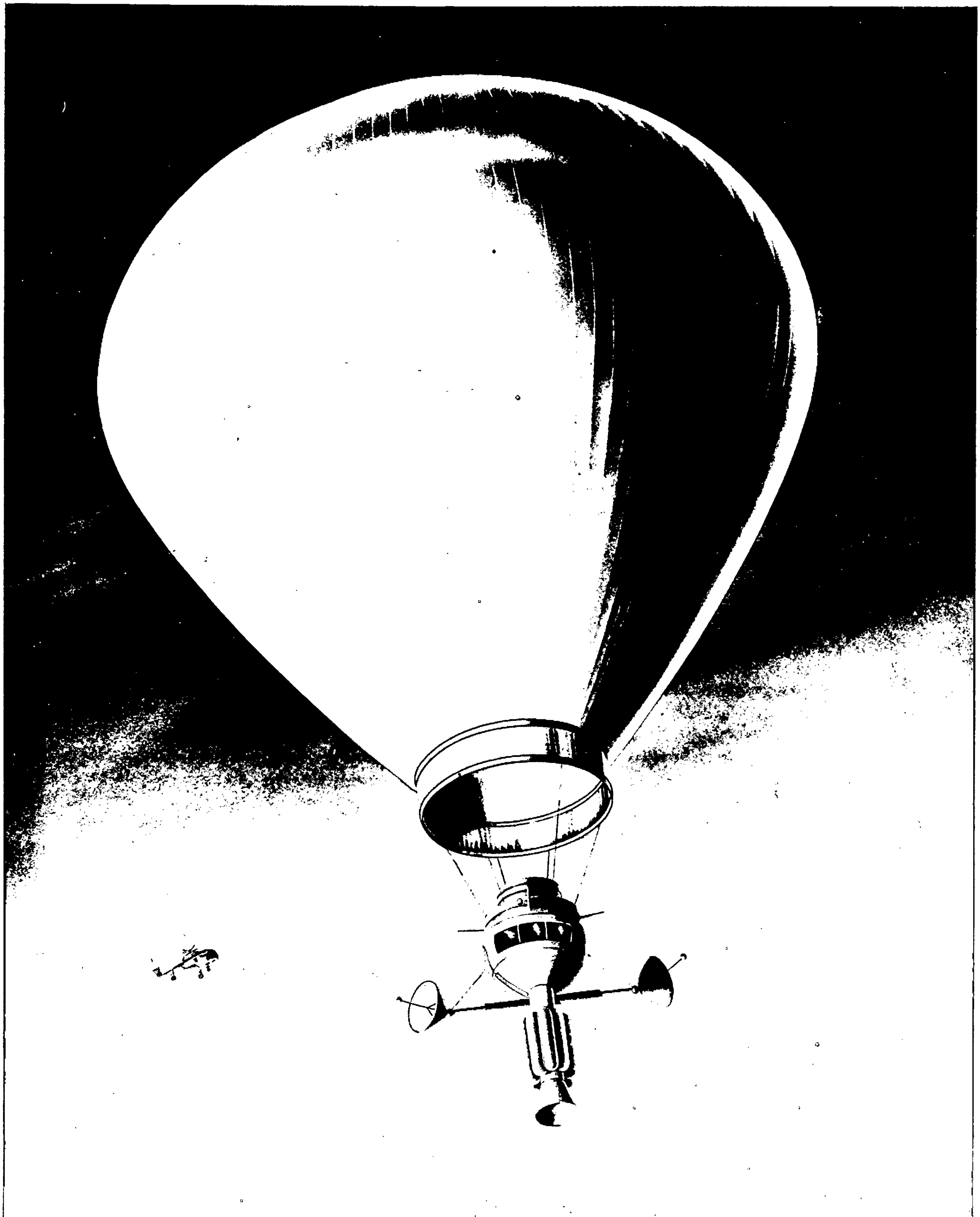

Figure 13

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