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TECHNIQUES DEVELOPED FOR HEAVY LOAD NON-EXTENSIBLE BALLOON FLIGHTS

BERNARD D. GILDENBERG

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HOLLOMAN AIR DEVELOPMENT CENTER

TECHNIQUES DEVELOPED FOR HEAVY LOAD NON-EXTENSIBLE BALLOON FLIGHTS

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HOLLOMAN AIR FORCE BASE, NEW MEXICO

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ABSTRACT

In order to successfully meet the Holloman Air Development Center requirements designated by Test Directive #5182-HI (Manned Balloon Program), new launching and tracking techniques were developed. The problems introduced by the half-ton payload are analysed and solutions discussed. A balloon shroud inflation system and the introduction of ground radio vehicles, a Balloon Tracking Control Center and a D. F. Loop for recovery, are the primary innovations.

MANNED BALLOON PROGRAM
FACILITIES DEVELOPMENT REPORT

Project Requirements

To successfully lift a 7-foot diameter, 1,000-pound sphere to altitudes ranging from 50,000 to 100,000 feet, MSL, on a non-extensible balloon; to float the load at these altitudes for durations up to 24 hours; and to recover the load in as short a time as can be achieved.

Pre-Project Capabilities

Prior to the initiation of MX-1450B, this Center had successfully flown four payloads of over 500 pounds, the maximum being 856 pounds. The maximum duration was 84 hours. A total of 150 plastic balloon flights had been flown since 1950.

Problem Breakdown

A. The Vehicle

1. For the minimum level, a 61-foot diameter, sphere-cone, 2.5-mil polyethylene balloon weighing 175 pounds would be a logical candidate. It would lift the half-ton payload to 55,000 feet, MSL. Another possibility, especially with its superior transverse stress properties, would be the 66-foot diameter, natural shape balloon. Weighing 164 pounds, the 2-mil version would attain 52,000 feet, MSL, with the MX-1450B load.

2. The largest polyethylene balloon, now in existance, which has been flown enough to be considered past the experimental stage, is the 116-footer. The 2-mil model will achieve 83,000 feet, MSL, in the natural shape configuration, or 86,000 feet, MSL, in the sphere cone configuration.

3. Basic interim level balloons would be the sphere-cone 72.8-footers (65,000 feet, MSL) and 90-footers (75,000 feet), in addition to the comparable natural shape balloons.

4. Higher altitudes can be achieved by clusters of the afore-mentioned balloons, or use of cells larger than the 116-footer which are still experimental items, or not yet in existence.

The following compares the qualtities of clusters, and "giant" balloons.

a. Reliability: In most cases, the individual balloons of a cluster being smaller will be more thoroughly tested vehicles than the giant balloon. However, the need for a successful performance by several balloons in contrast to the single giant balloon serves to equalize the reliabilities. The advantage is seized by the giant balloon, as the number of balloons in the cluster is increased. This advantage is demonstrated in the following examples.

b. Efficiency: Because of the large increases in surface area, increasing the number of balloons on a single flight is less efficient than increasing the total volume of a single balloon. As an example, a comparison is made between the experimental 1-mil, 178-foot diameter, "Super-Sky-Hook" and a cluster of 4 each 1-mil, 117-footers, both bearing the 1,000-pound load.

	Four 117-Footers	Single 178-Footer
Total Volume Cubic Feet	3,454,000	3,000,000
Total Weight Pounds	1,240	630
Maximum Altitude Feet MSL	106,000	109,000

As another example, consider a 2-mil, 145-foot balloon (hypothetical) weighing about 740 pounds, which would carry the load to exactly 100,000 feet, MSL, and would probably be not a great deal more trouble to launch than a 700-pound, 2.5-mil, 116-footer. Compare this single balloon with a cluster of three 2-mil, 117-footers, weighing a total of 1700 pounds, which would only attain 97,000 feet, MSL.

c. Launching Problems: Use of a giant size balloon introduces two basic problems.

(1) The top of the balloon, during inflation and launching, is further above the ground, necessitating light winds for even a deeper layer of air than usual.

(2) The size of the launching equipment must be increased. In a cluster, however, the balloons must be tied together by lengths of line at least 150 feet long. Consequently, after inflation, but before the load is launched, the cluster balloons will be even further above the ground than a single, giant balloon. Furthermore, the rigging becomes complicated, especially when more than two balloons are employed.

The launching equipment for the standard size balloons of a cluster is already on hand but will be needed in duplicate or more.

5. To be considered next is the structural strength of the plastic balloons.

a. The load tapes: Two principal types of load tapes are used with polyethylene balloons. (1) One inch wide acetate fiber pressure sensitive tape is rated 50 pounds test, and (2) Glass filament tape at 500 pounds test. Checks at this Center have found these items to test as low as 15 pounds and 350 pounds, respectively. An early test for MX-1450B, using a 45-fo t balloon constructed principally of fiber acetate load tapes, resulted in the tapes peeling off near its equator, after about 900 pounds of gas had been valved into the balloon. On the basis of this experience, together with reports by the University of Minnesota, the decision has been to order only continuous glass filament tapes (preferably #890, Minnesota Mining Company) for MX-1450B balloons.

b. The polyethylene sheet: The best performances with heavy loads, previous to this project, have been obtained using DE-2500 resin, double .001-inch polyethylene sheet. Equally fine performance, with laminated 2-mil sheet of the same resin, has been obtained by some of the first MX-1450B flights. Two-mil material, in general, is preferred so far because:

(1) The difference in floating altitude between a 1.5- and a 2.0-mil balloon of the same volume is so small that the extra safety factor and easier handling qualities of the 2-mil balloon is preferred.

(2) Capacity data for 2.0-mil balloons (with continuous glass filament load tapes) are known, as a result of tests conducted by the University of Minnesota. This Center has obtained permission through Air Research and Development Command Headquarters to use the Navy blimp hangar at Moffet Field, California, to run maximum inflation tests on 3-mil balloons. On the basis of these tests, it is hoped to determine if the extra safety structural safety factor on 2.5- and 3-mil balloons balances the lower floating altitudes. In addition, comparison will be made between the breaking points of sphere-cone and the newer natural shape balloons. Results of all these tests will be discussed in a later report.

B. The Load

1. The parachute test gondola has already been received and assembled at this Center. For the 20 successful flights required in Stage 1A, (Test Directive 5182-HI), however, a dummy 1,000-pound load is required.

2. At this time, three dummy loads have already been constructed and flown by this Center.

3. The present dummy load (see Figures 1-3) is simply an aluminum cylinder, with a sliding tray for instrumentation. The ballast reservoir is 10 cubic feet, with the filler hole openings on top of the cylinder. In addition, a rectangular section is located on top to contain the packed parachute. The cylinder alone weights 170 pounds, and has a capacity of 1,000 pounds of sand.

4. Until a successful parachute system has been established for this project, the dummy cylinder will be recovered with standard 24- or 38-foot parachutes with the sand being jettisoned initially. This process has not been an easy one, however, and the problems will be discussed in detail in the flight summaries, because it is felt that some of the incidents will be of great interest to the Wright Air Development Center Parachute Laboratory working on the final recovery system.

C. Inflation and Launching Techniques

1. Type of Inflation

The three types of inflation employed by organizations flying non-extensible balloons are:

a. The launch platform (Figure 4): This is the earliest technique applied, and is gradually being replaced. Employed with a wind screen, like the 40-foot structure at this Center (see Figure 5), it is acceptable for loads of 300 pounds or less. There are two principal disadvantages for heavier loads, however.

(1) The arms are locked near the equator of the balloon, where the stress (against the gas lift) is taken up by folds of the balloon material and tape. The load on a non-extensible polyethylene balloon is meant to be carried by the tapes and harness only.

(2) Since the payload is located some distance from the bubble of gas prior to release, horizontal motion of the payload is required in most cases. This is to avoid the payload from penduluming toward the ground. In addition, there is always the danger of shock on take-off, when the bubble finally takes up the load.

b. The covered wagon (Figure 5): One such device is located at this Center, and it is an excellent aid to inflation in stiff surface winds. However, it suffers the identical limitations upon release, as the launch platform. (See Sub-paragraph (2) above) The payload involved in MX-1450B obviously cannot be subjected to any of these launch hazards.

c. Vertical inflation: This is an excellent technique for heavy loads, and is the system chosen by this Center as the basic solution to this problem. The primary advantages are:

(1) After inflation is completed, the balloon and payload are already in the final relative flight positions, with the center of mass of the helium directly over the payload. Consequently, with no surface wind, the payload is lifted vertically and smoothly. In the presence of light winds, there is much less horizontal motion experienced than in other techniques, and no take-off shock whatsoever.

(2) The stresses during inflation and before release are applied to the parts of the balloon, which were built to negotiate these forces, namely, the load tapes and harness.

(3) The technique employed in a perfect calm, requires less layout preparations than any other technique.

The vertical inflation technique had been employed by this Center prior to the advent of MX-1450B. At that time, (see Figure 6) only two elements of "hardware" were employed. First, a boom at the end of which the load ring of the balloon was tied. Secondly, a reefing cloth was employed to restrict the gas to the top of the balloon in a tight, round bubble. After inflation, the boom was raised, the payload positioned underneath it and tied into the balloon. The reefer was then removed, and the balloon cut free from the boom. Final release was effected by severing the lines tying the payload to the launching cart. The process was smooth and direct with one principal disadvantage. Any wind of approximately 2 knots or more would commence to rotate the balloon about the vertical axis. In doing so, the polyethylene inflation tube would twist, and often terminate the inflation. The method therefore was too hazardous to risk any flight in winds of 2 knots or more.

2. In order to convert the vertical inflation technique described above into something more versatile for use with MX-1450B, the following modifications were developed:

a. A 40-foot diameter, 100-pound airplane cloth shroud cap, with eight 2,900-pound test hold down lines, was developed (see Figure 7). Use of this cap, in conjunction with the reefer, has already proved to more than double the surface wind capabilities of the vertical launch. In addition, a further step is being taken to make the cap and the reefer one continuous piece. It is hoped that this step will allow the inflation capabilities to approach 10-knot surface winds. Past statistics show that at dawn in the Tularosa Valley the surface winds are less than 10 knots approximately 90% of the time.

b. Tests have been made in an attempt to replace the polyethylene inflation tube by a rubber or plastic hose within the balloon. Such a technique would prevent the flow of helium from being quelched by twisting of the balloon. In conjunction with these tests, an improved helium diffuser technique has been devised by installing fine wire mesh baffles in the diffusers. This appears to provide a more satisfactory gas profile during rapid inflations.

c. In order to speed the inflation process, a method of increasing the pressure of the helium issuing from the trailer has been developed. This method is discussed in detail in the 23 May 1953 Test in the Appendix.

The accuracy of the inflation is also an important phase. The ascent rate of the balloon must be controlled carefully, since a rapid ascent is the primary cause of balloon bursts. Two steps have been taken in order to initiate further control of this factor.

(1) A Roots-Connersville flow meter is being obtained. Employed to meter the volume of gas leaving the helium trailer, it will eliminate a large number of indeterminable variables which contribute errors to the present system. Some of these are:

(a) Temperature gradients within the helium trailer.

(b) Volumetric variations of the individual helium trailer tubes.

(c) Variations in the grade of helium.

(d) Temperature changes occurring during the helium valving process.

(2) Command ballast techniques are soon to be adopted. With this system, the ascent rate can be planned to be deliberately slow, and adjusted during the ascent by dropping ballast, as commanded from the ground.

d. A polyethylene covered aluminum tube has been constructed to place within the balloon appendix, during the inflation. This prevents the harness rigging from pinching the inflation tube.

D. Tracking and Recovery Techniques

In order to facilitate tracking and recovery of balloons and payloads, three major steps have been taken:

1. A tracking control station has been established in the new 6580th Test Squadron (Special) Building at this Center.

2. Motor vehicles have been assigned to the Balloon Unit (Holloman Air Development Center) and have been equipped to provide adequate mobile ground tracking and recovery.

3. A direction finding loop antenna system has been designed and will provide a permanent long range tracking facility. These are described in detail below:

a. Balloon Tracking Control Station

The need for a central station to facilitate liaison with Center support units as well as to coordinate and direct the various tracking devices led to the establishment of the Balloon Tracking Control Station. The station is in continuous operation throughout a given flight. It is the duty of operating personnel to keep an accurate log of position and altitude data. These data are plotted and analyses are made of wind direction and speed. Actual balloon performance is compared with weather data transmitted over Air Weather Service teletype circuits and trajectory forecast revisions are made when needed. Communications equipment (radio and telephone) is available to maintain contact with the tracking aircraft and the ground vehicles. The control console for the DF loop antennae is located here. Radio communications equipment consists of:

(1) BC 610 Transmitter

(2) Hallicrafter Receiver

(3) Motorola Receiver and Transmitter

(4) AN/TRC-2 Receiver and Transmitter

(5) BC-640 VHF Transmitters

(6) BC-639 Receiver

b. A 90-foot high "wind charger" vertical radio tower has been ordered. It will provide circular pattern in azimuth to be operated with the BC-610 to provide coverage on 2229 kc (command separation) in addition to other communications frequencies. This equipment will also be used to effect radio controlled ballasting.

c. Mobile Ground Tracking: Prior to July 1953, ground recovery was accomplished by a Base recovery group. At this time a limit of 200 miles radius from this Center was established for this group's recovery activities. The Balloon Unit's requirements could not be met under this arrangement. Efforts were initiated for acquisition of recovery vehicles and recovery personnel to be assigned to the Balloon Unit. In August, a one-ton panel truck was acquired and preparations were made immediately for the installation of the following equipment:

(1) ART-13 Transmitter

(2) BC-348 Receiver

(3) ARN-6 Compass Receiver

(4) ARC-3 Receiver and Transmitter (100-156 mc)

(5) Motorola Receiver and Transmitter

(6) Plotting Board and Theodolite

This equipment has been installed and test runs made. The truck has not been used on actual flights because all necessary calibrations have not been completed. However, it is anticipated that it will be in operational use soon.

A second vehicle (weapons carrier) has also been obtained and has been outfitted with communications equipment of the following types:

522 Transceiver (VHF),
BC-348 Receiver (1.5-18 mc), and
BC-191 Transmitter (HF).

This vehicle has been used on operational flights. However, because of its relatively low rate of speed it is not completely satisfactory as a recovery vehicle under all conditions which are likely to be encountered. It is felt that the fast moving panel truck maintaining communication with the slower more rugged weapons carrier will provide a recovery facility far superior to any previous method used. It must be remembered, however, that the tracking aircraft in the final stages of a balloon flight is the best insurance against loss of a payload. Adequate communications at this time are essential.

A third vehicle (2-1/2 ton van) is being equipped to act as a communications relay station between the other two ground vehicles and the Tracking Control Station. It is planned that a portable DF loop antenna be installed on this vehicle as a supplementary tracking device.

Operating procedures for the vehicle are being worked out for various flight durations and conditions. The vehicles will be equipped to operate until the mission is completed.

Recently, five (1 Civilian, 4 Military) qualified missile recovery men have been assigned to the Balloon Unit. The experience of these men in recovery techniques ranges from two to five years.

d. DF Loop Antennae: Six tracking methods have been investigated for adaptability to balloon use. This study showed that the 1735 kc direction finding loop antenna was the most practical device with respect to simplicity and dependability, weight of balloon-borne instrumentation, range, and economy.

A prototype antenna has been constructed and tested on several balloon flights. The information obtained from these tests led to the construction of a larger loop and control console. The theoretical range for this loop is about 200 miles.

A shelter has been constructed on the roof of the new 6580th Test Squadron (Special) building and it is anticipated that the loop will be installed and operating soon. Plans are being considered to convert this loop to automatic operation. To complete the network it is planned that two more loops be located at suitable sites to provide triangulation.

FLIGHT SUMMARY FOR 1450B

Introduction

The requirements listed under Stage 1, Phase A, T. D. #5182-HI, state: Develop dependable and safe launching and lifting techniques for plastic balloons which are capable of carrying loads of 1,000 pounds to altitudes between 50,000 and 100,000 feet, MSL. Holloman Air Development Center responsibility will be to perform approximately 20 successful launchings and flights of this type.

A. The requirements listed under Stage 1, Phase B, state: Holloman Air Development Center responsibility will be to perform approximately 10 instrumented parachute descents from altitudes of 50,000 to 100,000 feet. There must be three consecutive successful descents with the ultimate recovery systems. Tests under Stage 1 may be combined, whenever feasible.

The last two stages are not intimately concerned with balloon launching development. (In this introduction, the primary concern is to define the vehicle development flights to be negotiated under Stage 1.)

B. The phrase "successful launchings and flights" must be discussed and expanded with regard to the primary statement, "develop dependable and safe launching and lifting techniques."

In order to make the launchings and flights "safe and dependable," the safety factors must be determined for various flight phases. This requires that inflations be made in ever-increasing winds until some velocity is experienced which prevents the inflation and/or a safe take-off. It required that each type of balloon be flown at high ascent rates until the balloon bursts. Only until the actual failing point for each vehicle phase is actually encountered, can we realistically state the safety factors. Consequently, there are flights which fail, yet which must be considered successful if they provide the information needed.

C. Also to be considered are flights which do not provide the initially desired information, but result in the accumulation of other useful data. Planning-wise, the procedure of declaring such flights successful (i.e., needed information was obtained although not at the planned time) may not be agreed with. However, because of the limitation of the number of flights (20-30) in this development stage, useful information must be considered, regardless of the order in which it is accumulated.

D. In conclusion, it appears, with the limitation of the 20-30 balloons which can be expended on the vehicle development phase, that the most practical goals should be:

1. To insure that all the safety factors are known for all the types of balloons under all possible conditions.

2. To obtain concise data on floating altitude characteristics of each balloon. (Actually, since this is a statistical problem, further information will also be obtained from the later stages.)

E. Flight Record

Flight #1 - HAFB-158, 28 July 1953

Program Stage:	Stage 1, Phase A
Balloon:	
Diameter	72.8-foot
Thickness	2.0 mil
Shape	Sphere-Cone
Weight	219 pounds
Appendix	Skirt type
Mfg.	Winzen
Payload: Dummy Cylinder	976 pounds
Inflation and Launching Method:	C-2 wrecker with canvas balloon reefer
Free lift:	10%
Surface Winds:	0.5 knots

Purpose: To check the ability of the various parts of this type balloon to support a 1/2-ton payload.

To check the accuracy of the rapid inflation method.

To check the arrangement on the dummy load.

Results: Maximum altitude: 9,000 feet, MSL

Flight duration: 1-3/4 hours

Discussion: There was a double load ring on this balloon. One of the rings broke before take-off; the apparent result of a weak weld. The remaining ring was bent into an oval shape, but successfully supported the load for the flight duration.

The launching and inflation technique was not being tested. It is a method which had proved to be adequate only with surface winds of 2 knots or less. This first flight had long been delayed because of abnormal surface winds for the past month. On the morning of this flight the winds were very light upon layout, but the synoptic situation indicated an increase very shortly. Consequently, for the first time at this Center a balloon was launched before sunrise. The effect of launching the balloon before it accumulated superheat, in addition to a free lift intended for a slow ascent rate, resulted in a slow rise to approximately 7,000 feet, MSL, where the flight leveled off. When the sun's rays finally contacted the balloon, it began to rise. A short time later, one of the safety circuits was activated. This circuit had been set to effect flight termination if the balloon did not attain 30,000 feet, MSL, 1-1/2 hours after take-off.

The completion of the circuit resulted in the blowing of a squib, which began to dump approximately 800 pounds of sand. Eight seconds later another squib was intended to blow the load line between the parachute and the balloon, thus effecting separation. As the sand was released, however, the balloon began to rise rapidly, gyrating wildly. This action apparently cut the separation wires and separation was never effected. Finally, at approximately 5,000 feet above the ground, the balloon burst and free fell with the payload to the ground, the parachute never opening. It was a packed parachute with no drag chute.

This sand-dump balloon separation process is not something that will be exactly duplicated in the Wright Air Development Center phases. However, with a 150-pound man leaving th gondola before separation, a minor variation of the above problem might have to be reckoned with. What makes the above incident even more noteworthy, however, is the fact that the load suffered little damage, despite the 5,000-foot free fall. The entangling balloon offered considerable drag on descent and cushioning upon impact.

Summary: The initial flight indicated that the load ring was a possible weak link in the balloon structure.

It seemed likely that the balloon would have continued to rise to floating altitude, notwithstanding the safety circuit. A release 15 minutes later might have made the difference. However, the final lesson appears to be that in order to be safe, the actual time of sunrise must be accepted as solid line of demarcation between normal, uninterrupted ascents and abnormal ascents.

The lesson learned, it might appear, is that such a flight with men aboard need not be considered. There have been cases, however, of a balloon leveling off at a low altitude under a temperature inversion. Most of these cases occurred at launch sites other than Holloman Air Force Base, which are frequented by strong frontal systems. Nevertheless, every possible source of hazard should be considered in connection with this project.

Flight #2 - HAFB-168, 16 September 1953

Program Stage:	Stage 1, Phase A
Balloon:	
Diameter	72.8-foot
Thickness	2.0 mil laminated
Shape	Sphere-Cone
Weight	241 pounds
Appendix	Skirt type
Mfg.	Winzen
Payload: Dummy Cylinder	972 pounds
Inflation and Launching method:	C-2 wrecker, reefing cloth, and shroud cap
Free lift:	11%
Surface winds:	0-2 knots

Purpose: To subject the shroud cap to a full scale inflation and launching test.

To obtain a preliminary check on the comparative tightness of this balloon-payload combination together with the use of the shroud.

To check the accuracy and efficiency of the "compensation partial" method of helium inflation.

To obtain further information on the sand dump mechanism.

Results: Maximum altitude: 63,400 feet, MSL

Flight duration: 3.7 hours

Discussion: The surface wind was too light to evaluate the shroud in the light of difficult inflation conditions. It was seen, however, that the balloon was under perfect control throughout all phases of the inflation. Considerable difficulty occurred during the process of pulling off the shroud. This had not been the case during the pre-flight test on the shroud when there was less gas in the balloon. On the basis of this flight, a formal release device will be developed for the shroud cap.

The ascent rate was almost exactly as desired, and provided preliminary verification of the accuracy of the "compensation partial" method. More flights are needed, however, to pass final judgment on the method.

The entire inflation required 37 minutes, compared with the 20 minutes required for the "half tube" inflation method. There was, however, an eleven minute delay occasioned by the transfer of hose and pressure gauge to a second helium trailer which contained the partials. The total time, therefore, could be shortened to a more satisfactory interval by obtaining the proper hardware to connect the pressure lines of two trailers.

Very comprehensive balloon performance data were obtained on this flight, as the White Sands Proving Ground-Holloman Air Development Center radar network tracked it throughout the flight.

The maximum altitude attained was 63,500 feet, MSL. The theoretical altitude from the graphs provided by the manufacturer was 62,900 feet, MSL.

A constant level, non-extensible balloon will ascend at some rate, which increases with altitude, and which can be to some degree, determined in advance by the percentage of free lift. When the balloon nears floating level, ascent rate decreases so markedly that it often takes another hour to attain the maximum altitude. At the top, the balloon either reaches a peak altitude and commences to descend immediately, or else it levels off for a while before descending. These plateaus are hard to spot because of the nature of the altitude measurements, and possibly, because they really do occur but rarely. The telemetered altitude is not continuous, the time and scale of the sensitive barograph most often is inadequate, and the balloons are usually out of radar range by the time they reach floating altitude. However, a large percentage of the barograph traces from previous balloon flights indicate a positive peak, rather than a plateau.

This flight did demonstrate a plateau for one hour. Out of 35 flights with good altitude data, only four others in addition to this one have indicated a plateau.

The overall descent average after reaching floating was minus 530 feet per hour (including floating) for 1.3 hours. This is well under the average of minus 1,000 feet per hour for 45 previously listed flights of all types. The most effective way to study the possible effect of the shroud cap on the balloon material is to compare balloon performance with a similar flight, without a shroud cap. The flight selected was HAFB-111, 2 October 1952, for Project Gopher. The balloon was identical, save for the fact that it was double 1-mil material instead of laminated. The inflation was vertical, without the shroud, but with the same reefer. The load was 773 pounds. Radar data were available. Both altitude curves may be seen on Graph Nos. 1 & 2.

In general, HAFB-168 seemed to be more stable, and commenced its descent twenty minutes later than HAFB-111. The overall descent values cannot be compared because the Gopher flight commenced to ballast after 50 minutes.

All of these factors indicate an altitude performance markedly better than average, despite the apparent rough contact of the shroud release. This might be explained by the superiority of laminated polyethylene or a greater stability, because of the greater mass of gas. Only more flight data with this type of payload and balloon will indicate these possibilities. In any event, the effect of the shroud was definitely not detremental, and the results are extremely pleasing.

The following sequence of events took place at flight termination:

Within one to two minutes of the set time on the balloon borne clock, the sand began to dump through four each, two-inch diameter holes in a plate, on the bottom of the ballast reservoir.

Twenty seconds later, with the sand still pouring out, the parachute and payload were separated from the balloon by the blowing of a cannon on the load line.

The load free fell for a little over three seconds, before the 38-foot cargo parachute deployed. Radar indicated about 10,000 feet per minute fall at this time.

The sand was not completely dumped until 2 minutes and 46 seconds after the parachute had deployed.

The time interval from the separation of the parachute and payload from the balloon, until impact was 3¼ minutes. The balloon was 62,860 feet, MSL, or 58,700 feet above the ground, at separation time.

It was apparent that there must have been well over 500 pounds of payload when the parachute opened, because 17 panels were found to be damaged, with one shroud line broken.

The final load, of only 190 pounds, however, was lowered successfully to earth and landed right side up, with no damages whatever.

Summary: In general, the flight was highly successful, providing a wealth of data. The seemingly rough treatment applied to the top of the balloon during the shroud cap release, compared with the satisfactory balloon performance, gives ample support to the reputed ruggedness of the 2-mil laminated sheet polyethylene.

For short flights, this test provides a fine proof of the good working trajectories which can be obtained almost any time of year by picking your altitude. (In this case the altitude was not picked. However, there is usually some altitude, at any time, where the winds are almost negligible.) The flight was airborne for 3.7 hours, was visible from the base to the naked eye, almost until parachute impact, and the impact was seen with 20 power optics.

Flight #3 - HAFB-170, 29 September 1953

Program Stage:	Stage 1, Phase A
Balloon:	
Diameter	72.8-foot
Thickness	2.0-mil laminated
Shape	Sphere-cone
Weight	241 pounds
Appendix	Skirt type with cardboard stiffeners
Mfg.	Winzen
Payload: Dummy Cylinder	1012 pounds
Inflation and Launching Method:	C-2 wrecker with boom, shroud cap, and canvas balloon reefer
Free lift:	11.5%
Surface Winds:	1-3.7 knots

Purpose: To obtain data on the floating altitude characteristics of a 72.8-foot diameter, 2-mil balloon for a fairly long, daytime flight.

To test the shroud cap release system number one.

To obtain further information on the accuracy of the "compensation partial" method of helium inflation.

To check the modified sand dump system, employing one 8-inch diameter opening at the bottom of the sand reservoir.

Results: Maximum altitude: 64,900 feet, MSL.

Flight duration: 6.2 hours.

Discussion: A good barograph trace and telemetered altitude data were obtained for the entire flight duration.

The overall descent rate was 910 feet per hour, slightly better than average, but apparently not as good as the first shroud flight (Flight #2), without the formal release system. Looking at the data more closely, however, we find that this balloon performance was actually better than that of Flight #2.

Flight Number	Minutes on the Plateau	Descent Rate Following
Flight #2	57	2106 feet per hour for 0.35 hr
Flight #3	130	1971 feet per hour for 1.9 hr

Summary: This flight, consequently, was again extremely satisfactory. It demonstrated the second longest plateau out of the 170 flights flown to date at Holloman Air Development Center.

With three out of the six total flights indicating plateaus, having gross loads of 1,000 pounds or more, the conception of greater stability because of larger gas masses seems to become more likely.

A shroud release system employing lines which ran completely up and over the apex of the shroud was employed. The release was still not satisfactory, although it was considerably easier than using just the lines attached to the circumferences as in the previous test.

The "compensation partial" inflation system again provided a very satisfactory ascent rate. This time, with only one helium trailer involved in the inflation, the total inflation duration was only 26 minutes. This interval is but 6 minutes longer than the average "half tube" inflation, the small time discrepancy appearing justifiable on the basis of the former's superior accuracy.

Because of the unforeseen rigidity of a special cap covering the 8-inch hole at the bottom of the sand reservoir, the sands did not dump. (Wires supporting the cap were successfully blown, however.) The 1,012-pound load, consequently, was lowered to earth by two 24-foot personnel parachutes, flown side by side. The parachutes were not damaged, although they demonstrated considerable twisting, and spilling of air during the descent. The bottom of the aluminum cylinder was severely bent, but the ballast reservoir was untouched, and the instrumentation suffered little damage.

Flight #4 - HAFB-171, 2 October 1953

Program Stage:	Stage 1, Phase A
Balloon	
Diameter	90-foot
Thickness	2.0 mil laminated
Shape	Sphere-Cone
Weight	337 pounds
Appendix	Skirt type
Mfg.	Winzen
Payload: Dummy Cylinder	1,246 pounds
Inflation and Launching Method:	C-4 wrecker with canvas balloon reefer and shroud cap
Free lift:	11.5%
Surface Winds:	0-2 knots

Purpose: To determine the adaptability of the current launching inflation methods and hardware (reefer and shroud) relation to the 90-foot diameter, sphere-cone balloon.

To obtain data on the floating altitude characteristics of a 90-foot diameter, 2-mil, sphere-cone balloon, for a full duration daytime flight of approximately 10 hours.

To obtain further information on the accuracy of the "compensation partial" inflation system.

To check the modification on the destruction device for removing the cap covering the hole at the bottom of the sand reservoir.

Results: Maximum altitude: 55,080 feet, MSL.

Flight duration: 1 hour, 5 minutes.

Discussion: The present reefing cloth was found to be approximately 10 feet too short and several inches too narrow for the 90-foot diameter balloon. As a result, another reefer is being built which will fit this balloon, and perhaps 116-footers. Nevertheless, the fit was sufficient to complete the inflation successfully.

The shroud cap appeared to fit the 90-footer very well. In general, the inflation did not appear any more difficult than with the 72.8-footers.

The balloon burst before reaching floating, at an altitude of 55,080 feet, MSL. The overall ascent rate was 792 feet per minute. Normally, this would be considered a good average for a polyetheylene balloon flight. The previous highest ascent rate with the MX-1450B load was 780 feet per minute on Flight #2. However, that test included a gross load of 1,032 pounds. The 792 feet per minute is with a gross load of 1,583 pounds. With gross loads over 2,000 pounds, Project Gopher encountered 14 balloon bursts out of 16 attempts, mostly due to ascent rates previously considered average. These bursts occurred at the base of the stratosphere where the coldest temperatures are encountered. It is worth noting, consequently, that at 54,472 feet, MSL, on the previous day a temperature of -72.9 degrees Centigrade was recorded at Holloman Air Force Base. This is 3 to 4 degrees colder than the brittle temperature of polyethylene, 18 degrees colder than the standard atmosphere, and 3-5 degrees colder than the average minimum temperature aloft for the month.

One of the aims of this phase, as stated in the flight summary introduction, is to learn the safety factor for ascent rates with the various balloons. There are these possibilities, however:

The balloon burst because of the temperature being below the brittleness demarcation. If the ambient temperature had been less than -70 degrees Centigrade, the same ascent rate would have been safe.

Because of the large gross load, approaching Project Gopher dimensions, the ascent rate must be lowered, no matter what the temperatures.

Actually, of course, the ascent rate was a little on the high side of what was desired, namely 500-700 feet per minute. It would be advantageous to fly another 90-footer through a similarly cold layer at 600 feet per minute.

The "compensation partial" system still provided close results. The last three flights have varied only between 712 and 792 feet per minute.

Summary: The main objective of the flight, to test the fit of the launching "hardware", was accomplished and without hazarding the flight. The secondary objective was by fate replaced by an objective that would have been applied in a later flight. Instead of floating altitude data, ascent rate safety factor data were obtained. The latter, of course, is just as important. In the overall picture, the flight was satisfactory supplying both useful and sufficient data.

Flight #5 - HAFB-172, 15 October 1953

Program Stage:	Stage 1, Phase A
Balloon:	
Diameter	72.8-foot
Thickness	2.0 mil
Shape	Sphere-Cone
Weight	240 pounds
Appendix	Tubular type skirt, 2 x 1 mil material
Mfg.	Winzen

Payload: Dummy Cylinder	1,042 pounds
Inflation and Launching Method:	C-2 wrecker, with canvas balloon reefer (unlacing type) and shroud cap.
Free lift:	11%
Surface Winds:	1-3 knots

Purpose: To test the new shroud cap release system. This method involves the unlacing of the cap which has been split into two parts.

To test the new reefing cloth, which also has been modified with an unlacing device. It is felt that this method would eliminate possible effects of frictional damage that could be affected by the previous sliding reefer cloth.

To obtain floating altitude data for four or more hours in order to compare the effect with Flight #3 of a cleaner shroud release upon balloon performance.

Results:	**Maximum altitude:**	62,700 feet, MSL
	Flight duration:	35 plus hours

Discussion: The split cap release worked smoothly and efficiently.

The new unlacing reefer, which had been constructed so that it would fit 90-footers and probably 116-footers, proved to be slightly large for a 72.8-foot Gopher type balloon. This made the unlacing process a very precise task. At one point during the inflation, the cloth was unlaced a little bit too far below the base of the bubble, and the cloth fell down. Before the next test, the lacing system will be modified to prevent such occurrences.

Complete altitude data are not available, because the barograph trace has not yet been reduced, and the flight was only within radar range for 2-1/2 hours. However, a double theodolite check after 8-1/2 hours of floating indicated a descent of 590 feet per hour. This is much better than average, and, more important, it easily exceeds the 910 feet per hour descent of Flight #3 for only 4 hours of floating. Thus far, therefore, the split shroud cap release results in considerably improved balloon performance.

Command separation gear was not on hand to be used, and the clock cutdown failed. The balloon was sighted east of El Paso, 24 hours after take-off. Since recovery has just been achieved, the flight will supply altitude data for at least a 36-hour flight of an unballasted flight with this size cell.

Optical tracking from the Balloon Tracking Control Center lasted for 11 hours.

Summary: Since the barograph data is now available, this flight is sidered a 100% success, as far as accomplishing purposes are concerned. The trial of modified hardware was successful, and enough altitude data were obtained to indicate better balloon performance with the minimum abrasive qualities of the modified hardware. The barograph data are needed for more concise details such as plateau information.

This flight will actually serve the purpose of two flights, since one or two overnight flights are needed on the 72.8-footer in this phase. The morning position near El Paso indicates (from wind flow information) that the flight could not have been lower than 50,000 feet, MSL, at this time. This indicated a nighttime descent rate at least equal to the daytime descent rate, and perhaps less. In the only other records of overnight unballasted descent rates on hand, six out of seven indicated greater descents at night.

Flight #6 - HAFB-175, 27 October 1953

Program Stage:	Stage 1, Phase A
Balloon:	
Diameter	116-foot
Thickness	2.5 mil
Shape	Natural
Weight	590 pounds
Appendix	Tubular type skirt
Mfg.	Winzen

Payload: 55 gallon drum, with 1,002 pounds control package on top

Inflation and Launching Method: C-2 wrecker with unlacing canvas balloon reefer, and shroud cap

Free lift: 7%

Surface Winds: 0-2 knots

Purpose: To test the adaptability of the launching hardware and techniques to the 116-foot diameter balloon.

To attempt a purposeful slow ascent rate, in accordance with Project Gopher experience with this size balloon, and heavy payload.

To obtain daytime altitude performance data with this balloon and payload combination.

Results:	Maximum altitude:	81,600 feet, MSL.
	Flight duration:	48 hours plus.
	Ascent rate:	850 feet per minute

Discussion: The shroud cap seemed to fit the 116-foot diameter balloon precisely. Actually, for gross inflations 200 pounds or more greater than the 1700 pounds on this flight, it might have to be perhaps five more feet in diameter. But for 1,000 pound payloads, it has now been established that the present shroud cap will fit balloons from 61 to 116 feet in diameter.

Summary: The laced reefer appeared to fit the big balloon precisely, in diameter, being about 10 feet short in length. During the inflation, however, a few of the loops hung up, right at the base of the bubble, about 120 feet above the ground. This dilemma was solved by lowering the bubble with the eight hold-down lines, until the loops could be contacted from the top of the covered wagon. At this time, there was approximately 900 pounds of gas in the balloon. This event, again demonstrates the versatility of the shroud cap.

It had been decided to give this balloon only 7% free lift, in an effort to attain an ascent rate between 300 and 500 feet per minute. The release was delayed for 3/4 of an hour, however, and considerable superheat was accumulated. In fact, the flight actually averaged 1,060 feet per minute, up to 40,000 feet, MSL. Mindful of the Project Gopher experience of 14 balloon bursts out of the first 16 flights with 116-footers, the tracking aircraft and vehicle were alerted for a burst when the flight entered the layers of minimum temperature, near 60,000 feet, MSL. By the time the balloon attained this level, much of the superheat had been dissipated, but the ascent rate was still 850 feet per minute. This was 60 feet per minute faster than the burst experienced on Flight #5, with the 90-footer, and some 400 feet per minute faster than the ascent rates advised by Project Gopher. Much to our amazement, however, no burst occurred, and the ascent rate slowed progressively until it eased into floating level. Three radiosonde runs taken within 24 hours of the flight, indicated that the minimum temperatures were varying between 60 and 62 degrees Centigrade. This is warmer than the average of 64 for last October, and 12 degrees warmer than the minimum temperature, the day the 90-footer burst.

No daytime altitude performance can be obtained until the barograph is recovered. The trajectory on the second day indicated the flight was between 55,000 and 65,000 feet, MSL. The flight was aloft over Key West, Florida, on the third morning, which means the earliest probable termination would be that evening. A 60-hour flight on an unballasted balloon attests to the fact that the cell was extremely tight.

In accumulating ascent rate safety factors, therefore, it is apparent that the temperature factors must be carefully integrated.

General: The control instrumentation antenna snarled on the edge of the launch cart at take-off, and was snapped off. Consequently, no telemetered altitude data, or command cut-down was possible.

The flight was again tracked optically until the sun set on the balloon, a duration of 9-1/2 hours, and down to a 3.7 degree elevation. Generally, optical tracking is regarded only as a supplementary, temporary device. The extreme visibility provided by the high altitude (4,100 feet, MSL) and desert skies at Holloman Air Development Center, however, converts the device into a major tracking element. The six flights for this project, thus far, have been tracked optically for an average of 5.5 hours per flight. The range has been up to 150 miles. This is no mean statistic, when you consider the equivalent tracking distances in the eastern portion of the country; a balloon over New York City as seen from Baltimore, or a balloon over Cleveland as seen from Dayton. Actually, the most important result of this optical capability, is that every one of the six flight was tracked for the entireties of the intended flight durations.

Despite the fact that the balloon could not be tracked overnight, forecasting and communication capabilities resulted in the balloon being picked up by 0900 hours, CST, on the second morning of the flight. The flight was forecast to be in the area near Austin, Texas, at dawn. At 0700 hours, MST, Bergstrom Air Force Base operations at Austin, was contacted. By 0800 hours, MST, visual contact was reported near San Antonio, less than 100 miles away. Negotiations had been initiated to use the MARS network on such emergencies, and a trial run was provided. Information on the balloon was broadcast to ham operators close to the trajectory. Throughout the day, positions were reported to Holloman Air Force Base operations, through Carswell Air Force Base, from Kelly Air Force Base, B-36s and other aircraft in the vicinity, and MARS observers. The sunset position was given as near Corpus Christi, Texas. The dawn position was forecast to be 200 miles west of Florida, between Tampa and Key West, a NOTAM to this effect was sent out over the airways, that night MARS operators in Florida were alerted. That morning an operator in Key West actually did sight the balloon.

All of these details serve to provide a lesson for the final phase of the project, on perhaps an overnight flight, with the floating laboratory. In this case, although the balloon communication safety factor will be considerably increased, even the one chance in fifty, perhaps, that communications would fail during the night, should be considered, in this case instead of hazarding the dangers offered by a bail out in the night, without the recovery personnel being close by, it would seem advisable to wait until daylight. Then with the capabilities just demonstrated, the flight should be rejoined by the tracking vehicles and aircraft, just after dawn.

STATUS OF THE OPERATIONAL PHASE OF THE MANNED BALLOON

PROGRAM AS OF JANUARY 1954

1. Balloon Summary

Received (and used) from WADC	Successful Flights
8 each 72.8 footers	6
3 each 90.0 footers	1
3 each 116 footers	1
1 each 72.8 footer	ground test

Supplied by HADC	
1 each 45 footer	0
1 each 61 footer	ground test
3 each 72.8 footers	0
2 each 92.5 footers	2
1 each 94 footer	0

2. Shroud Inflation Techniques

a. Pre-Shroud Flights	Shroud Flights
1 success out of 5 attempts	7 successes out of 14 attempts
	(2 failures due to instrumentation)

b. In total tests with the shroud, involving inflation only, there have been 13 successes out of 16 attempts.

c. There have been three completed inflations of 116 footers, out of three attempts (Figure 7). One had to be destroyed because of instrument failure, a second was found to have been damaged by the reefer, and the third flew successfully for more than 60 hours.

d. Maximum wind condition for a successful attempt has been in a 7-knot wind measured at an elevation of 20 feet with an estimated 10 knots at balloon bubble height.

e. A new and larger shroud, constructed of nylon, is in the process of fabrication. It will be employed in an attempt to keep the balloon bubble on the ground, during the entire inflation. It is hoped that this technique will increase inflation capabilities to at least 10 knots.

3. Actual launching experiences

a. Out of 10 launching attempts, 9 have been successful. The single failure was due to under inflation. The payload, however, was undamaged in all 10 attempts.

b. A new launch cart is being designed for the payload.

4. The number of flights which can be designated successful, under the conditions of Stage 1 of T. D. #5182-HI, are ten.

5. The maximum payload weight has been 1,246 pounds. The average for the eight flights, 1,042 pounds.

6. The maximum altitude for the eight flights has been 81,600 feet, MSL.

7. The maximum duration has been something in excess of 8 days. The average of the remaining seven flights has been 7.5 hours.

8. Tracking and Recovery Techniques

a. Recently, a 2-1/2 ton van has been equipped to act as a communications relay between the other ground vehicles, the Balloon Tracking Control Center, and the aircraft. Since the adoption of this system, there have been 12 consecutive successful recoveries.

b. A second radio panel truck and two radio equipped pick-ups are being obtained. This will result in the use of five ground vehicles on tracking missions.

c. The priority use of two L-20 aircraft (arriving 1 February) has been granted.

d. All four attempts with the Aero Med command cut-down unit have been successful. The maximum range has been 115 miles.

APPENDIX

1. Problem: To check a proposed method of maintaining a rapid flow of helium from the trailer during a vertical inflation.

a. It had been observed that during an inflation when 10 or more tubes of the trailer were employed, the final 500 psi of the gas from each tube would flow out at an increasingly slow rate. It took, for instance, 11 minutes on one test to drain 9 tubes from 250 psi down to zero. Vertical inflations must be performed during selected periods, when the surface winds are relatively light. Such periods may be of short duration and it is imperative, consequently, that inflation rates be greater than the magnitudes exhibited by the standard procedures.

b. The method proposed by the Balloon Unit as a solution to this problem was to employ double the amount of tubes needed for the inflation. As a result, the tubes would only be valved out to the point where they were half full. Since this value (approximately 1,100 psi) is well above the pressure where the inflation rate is appreciably decreased, the total inflation time should be proportionately decreased.

c. This solution is simple and there was no doubt concerning its effectiveness as a time saver. The only complication involved was that of accuracy. When a full tube of helium is emptied into a balloon, one can be sure that all of the computed lift has been delivered. However, extraction of only part of a tube poses some problems. Suppose, for instance, a tube originally contained 2,000 psi of gas at T_1 degrees Centigrade, and it was desired that half of this amount be extracted. When the pressure gauge indicated 1,000 psi and the main valve is closed, however, we do not know exactly how much lift has been extracted. Because of the decrease of pressure of the gas within the tube, the temperature has also dropped. Since it has not been possible up to now to modify the (Navy) helium trailers with thermocouples, a fairly large source of error is introduced. Special tests made a year ago with the use of thermocouples indicated an average error of minus one pound per tube, and a maximum of minus three. This, however, was for only the valving of one tube at a time. It is probable that the temperature drop, and consequently the error per tube, would be larger when 25 tubes were being valved simultaneously. A two-pound deficit per tube, in a 25 tube inflation, would almost halve the free lift in a 1,000 pound load inflation.

d. This source of error will be eliminated in the near future by:

(1) Purchase of a summation flowmeter. The Balloon Unit at present has sent out desired specifications to various companies.

(2) Construction of a spring scale for measuring lift on vertical inflation. Blueprints have already been obtained. There is some question of accuracy with such a device, but it should be able to detect deficiencies of 50 pounds or more.

e. For immediate use, a formula developed by General Mills Aeronautical Research Laboratory was chosen for study. This formula predicts at what gauge pressure the valve should be turned off, in order to extract the exact mass of gas needed. The "cut off" pressure is always lower than the standard computed pressure, because of the drop in temperature. Actually, if the pressure gauge were watched for 30 minutes after the cut-off, the pressure would climb back to the standard computed pressure, as the temperature of the tube recovered.

This formula was originally checked here a year ago with the aid of thermocouples. This result was very satisfactory, (predictions were something less than within 0.4 pounds per tube), but the tests were run on tubes which were drained individually. For MX-1450B, consequently, it was necessary to check the equation for many tubes draining simultaneously. In order to accomplish this, a ground inflation test was performed on 23 May 1953.

2. Test equipment employed:

a. One each 20-foot diameter, 1.5-mil, 12-pound polyethylene non-extensible balloon, with a volume of 4,500 cubic feet.

b. One each platform scale

c. One each 200 pound shot bag

d. Five tubes of helium at 2270 psi each

e. One each ground cloth

3. Test Procedures:

a. The balloon was laid out on the ground cloth, and the 200-pound shot bag tied into the load ring.

b. The 3-mil, red, 5-inch diameter inflation tube (which was too small for the diffuser at the end of the rubber inflation hose attached to the trailer) was withdrawn, and a standard 10-inch diameter tube inserted.

c. Five full tubes from the helium trailer were opened into the manifold, and allowed to equalize for 30 minutes.

d. At the end of this period, the pressure gauge and ambient temperature were recorded:

Gauge pressure	2,270 psi
Ambient temperature	65 degrees F.
Time	0810 hours MST

e. The gauge pressure was corrected from the calibration curve:

Corrected pressure	2,250 psi

f. The shot bags were placed upon the platform scale.

g. Gas was valved rapidly into the balloon.

h. The flow was cut off suddenly, when the tubes were less than half emptied. (The lower the pressure a partial is valved to, the less the error, as all the lift curves converge toward zero.)

i. The cut-off gauge pressure and the apparent reading of shot bag upon the platform scale were recorded:

Gauge pressure	1,390 psi
Corrected gauge pressure	1,375 psi
Shot bag weight	69 pounds
Time	0813 hours MST

4. Computations:

a. The total lift of gas inserted has been:

Apparent loss of weight of shot bags	200 pounds
	minus 69 pounds
	equals 131 pounds
Weight of balloon	12 pounds

Gross inflation equals 12 plus 131 equals 143 pounds.

b. The valving rate was 47.5 pounds per minute, about the same rate that 1,000 pounds has been inserted into a 45-foot diameter balloon, on a MX-1450B "hot" test. The temperature drop, consequently, must have approached reality as far as the rate of valving is concerned.

c. The original General Mills equation is:

$$\text{Cut off pressure} = 10{,}000 + .5\ IP \pm \sqrt{(10{,}000 + .5\ IP)^2 - 20{,}000\ FP}$$

where IP equals the initial tube pressure 1,375 psi FP equals the recovery pressure, or that pressure which the tube will assume after the valving ceases, and the temperature of the gas has recovered to the same reading indicated at the initial pressure reading. Cut-off pressure equals the pressure at which the valve must be turned off, so that a mass of gas equivalent to IP minus FP at the intial temperature will have been successfully extracted. In this test, this cut off pressure (which was in this case selected rather than computed) was 1,375 psi.

d. The final pressure FP, has to be derived by working backwards, with the test data and standard inflation charts.

(1) Total lift inserted into balloon - 143 pounds

(2) Lift per tube, for the five tubes - 28.6 pounds

(3) Lift per tube, with initial pressure and temperature (from the inflation charts) - 80.5 pounds

(4) Pounds lift of gas to be left in each of the five tubes, in order to attain the 143 pounds gross inflation - 80.5 minus

28.6 equals

51.9 pounds

per tube

(5) The final pressure equivalent to this lift per tube (4), FP, obtained from the inflation charts - 1,415 psi

e. Now that all the variables in the equation are accounted for, the values can be inserted to find out how valid is the relationship.

(1) Substituting in 4. c, we have:

$$1,375 = K\left(10,000 + .5\,(2250) + \sqrt{(10,000 + 1125)^2 - 20,000(1415)}\right)$$

where K is the "validity" factor, or that number which the phrase on the right hand side of the equation must be multiplied by, to obtain the correct cut-off pressure, for our particular test.

(2) Simplifying, let $a = 1,375$ $b = 11,125$ $c = 28,300,000$

so, $a^2 = 1,890,625$ $b^2 = 123,765,625$

(3) The equation now may be written as:

$$\frac{a}{K} - b = (b^2 - c)^{1/2}$$

squaring

$$\frac{a^2}{K^2} - \frac{2ab}{K} + b^2 = b^2 - c$$

$$a^2 - 2abK + cK^2 = 0$$

$$K = \frac{ab \pm (a^2b^2 - a^2c)^{1/2}}{c} = \frac{ab \pm a(b^2 - c)^{1/2}}{c}$$

$$= \frac{a}{c}\, b \pm (b^2 - c)^{1/2}$$

(4) Substituting the appropriate values for a, b, c, we find that

$K = 1.015$

5. Conclusions:

a. The value of K is close enough to 1.00, that we might conclude that the equation is sufficiently valid as it stands. This is especially so when we realize that:

(1) The 15 tests made with the individual tubes a year ago resulted in values of K with deviations from this new value, within the accuracy limits of the test instruments.

(2) These consistent answers have been obtained despite the possibility of sources of error, like the plus or minus 7.5 psi accuracy of the pressure gauge, and the variations in tube temperatures before the valving process and after the tube "recovery".

b. It seems reasonably apparent, therefore, that further ground test checks on this corrective equation can tell us little more, and that the first few successful ascents with the 1,000-pound load will provide the next data of importance in relation to this problem.

c. The accuracy of the equation as it stands now, therefore, must satisfy, but how accurate is this in a typical MX-1450B flight.

(1) Let us take a typical gross inflation:

Payload	1,000 pounds	
72.8-foot balloon	250	
Free lift	110	(8.8% gross load)
	1,360 pounds equals gross inflation	

(2) At an average lift of 85 pounds per tube, this inflation calls for 16 full tubes. With our half tube accelerated method, we will use 32 full tubes.

(3) Valving the tubes into the balloon until they are half emptied would supposedly call for valving until the pressure gauge reads a little over 1,000 psi. Because of the drop in temperature, however, we have to valve to some pressure 50 psi or so less than this as predicted by the corrective equation.

(4) Because of the limitations of our measuring instruments, one cannot, however, justifiably apply a correction to the answer provided by the equation. (As discussed in 5.a) If the equation says that cut-off pressure is to be 1,000 psi, that is the value which will be employed.

But suppose that the K = 1.015, as calculated from the ground test, was exactly right, despite the accuracy limitations with such a small magnitude difference. On this particular flight, there would be a discrepancy of 15 psi. This does not sound like a bad figure, for the smallest division on the pressure gauge is 20 psi. However, multiply this 15 psi by the 32 tubes which are being employed simultaneously, and there will be a discrepancy of 480 psi, or 18 pounds of lift, at room temperature. This would change the free lift by 1.5%.

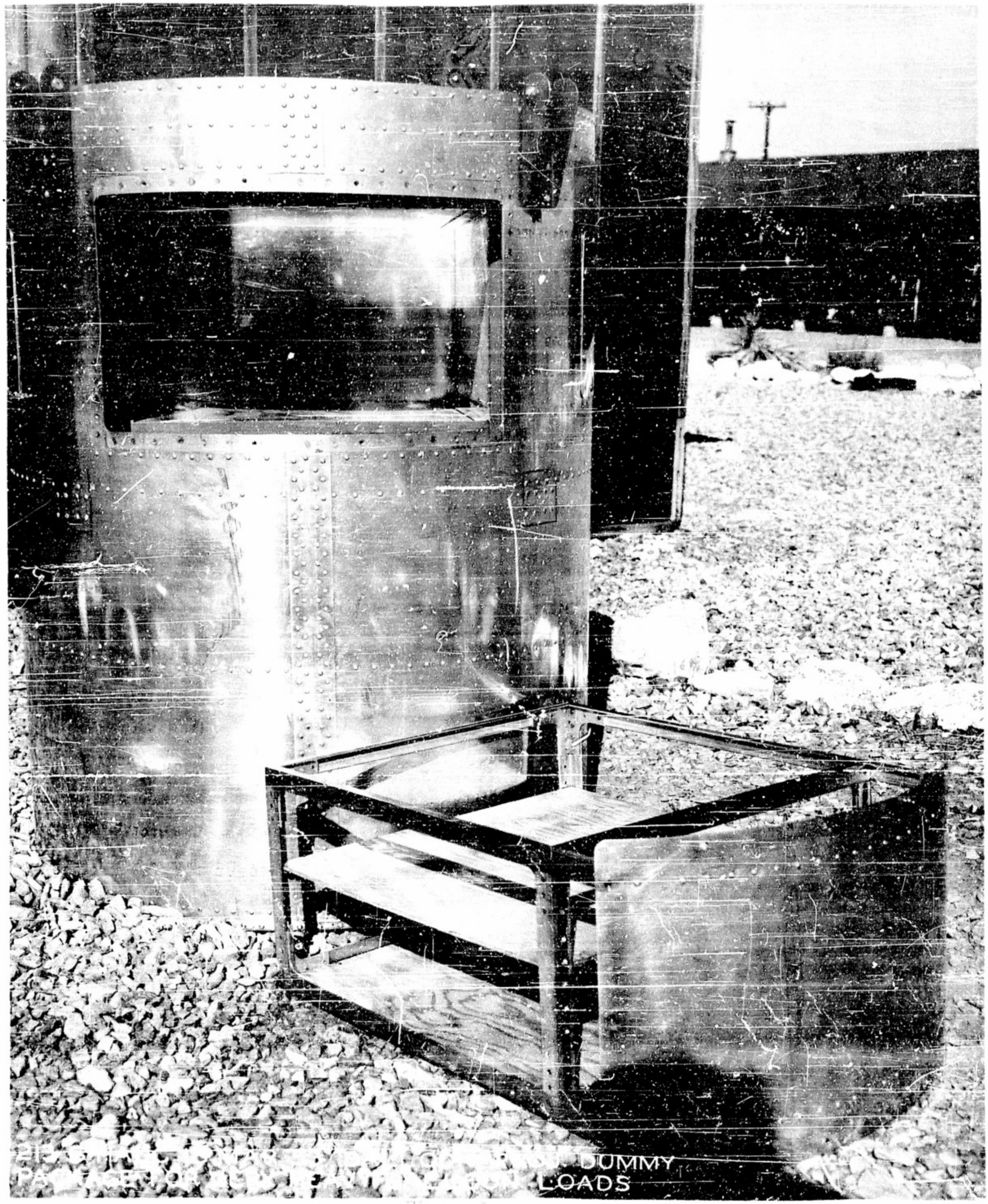
(5) The most important factor, here, of course is the 32 tubes being employed. No matter what the source of error is, the magnitude becomes important when multiplied by 32. The pressure gauge, for instance, would be responsible for calculation fluctuations of plus or minus 9 pounds of lift. In a comprehensive report on inflation techniques (to be distributed soon by 6580th Test Squadron (Special), Holloman Air Development Center), 15 sources of error, all of a magnitude of not less than 0.2 pounds lift per tube, are discussed. All of these become important when 32 tubes are involved.

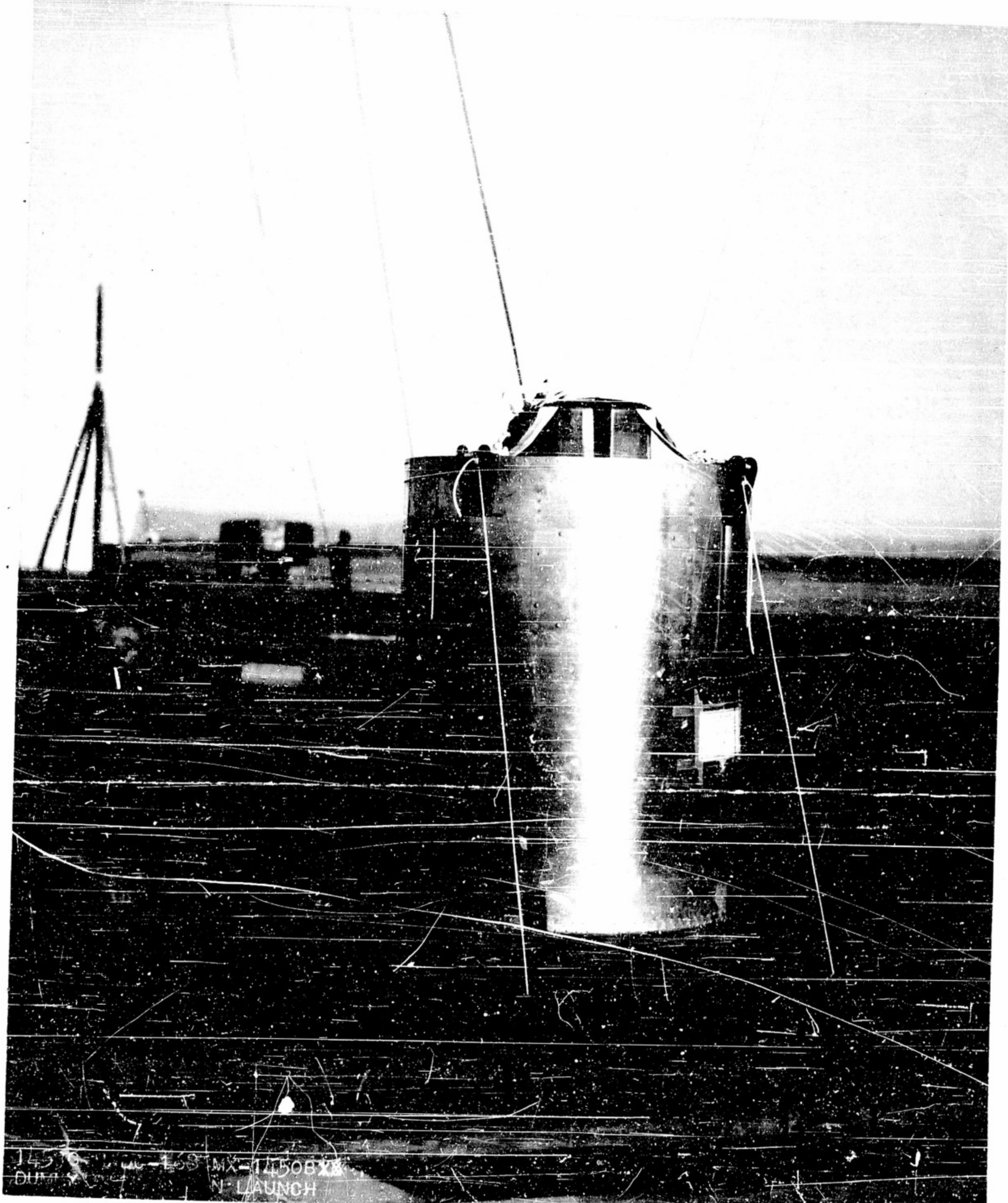
d. Summing up, it can be concluded that the equation will probably provide answers as accurate as any of the other inflation measurement techniques currently employed. The limitations of these accuracies, however, will become more important when magnified by the extreme quantities of gas to be employed for the MX-1450B flights.

6. Recommendations

a. No further ground checks should be made with this system, unless some method of weighing off 1,000-pound loads is obtained before the first few actual balloon ascents. The ascent rates demonstrated by the first flights will provide the most important answers.

b. A method of measuring the lift by use of a spring scale, tied in between the ground and the load ring, should be initiated.


DUMMY
LOADS



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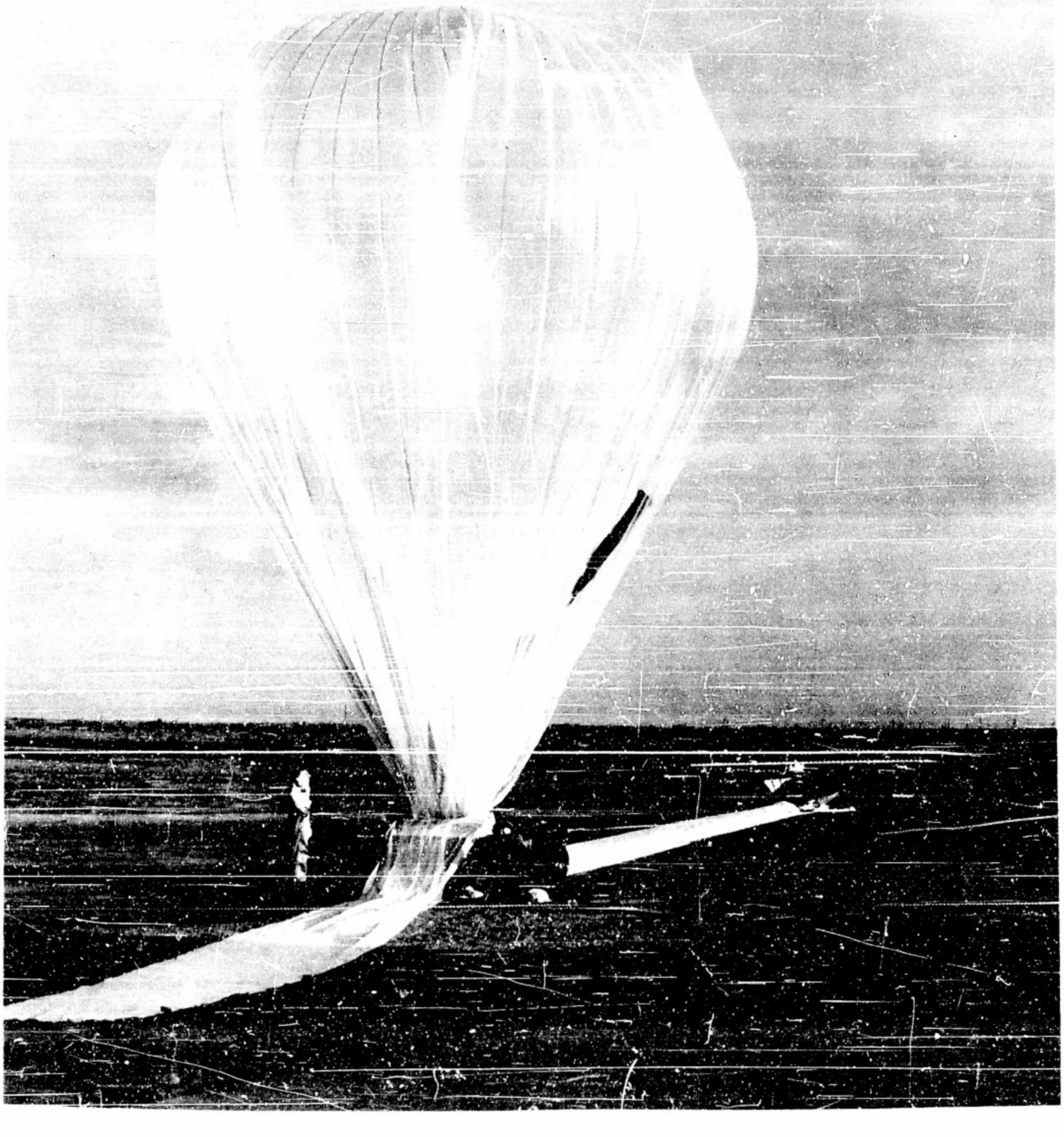

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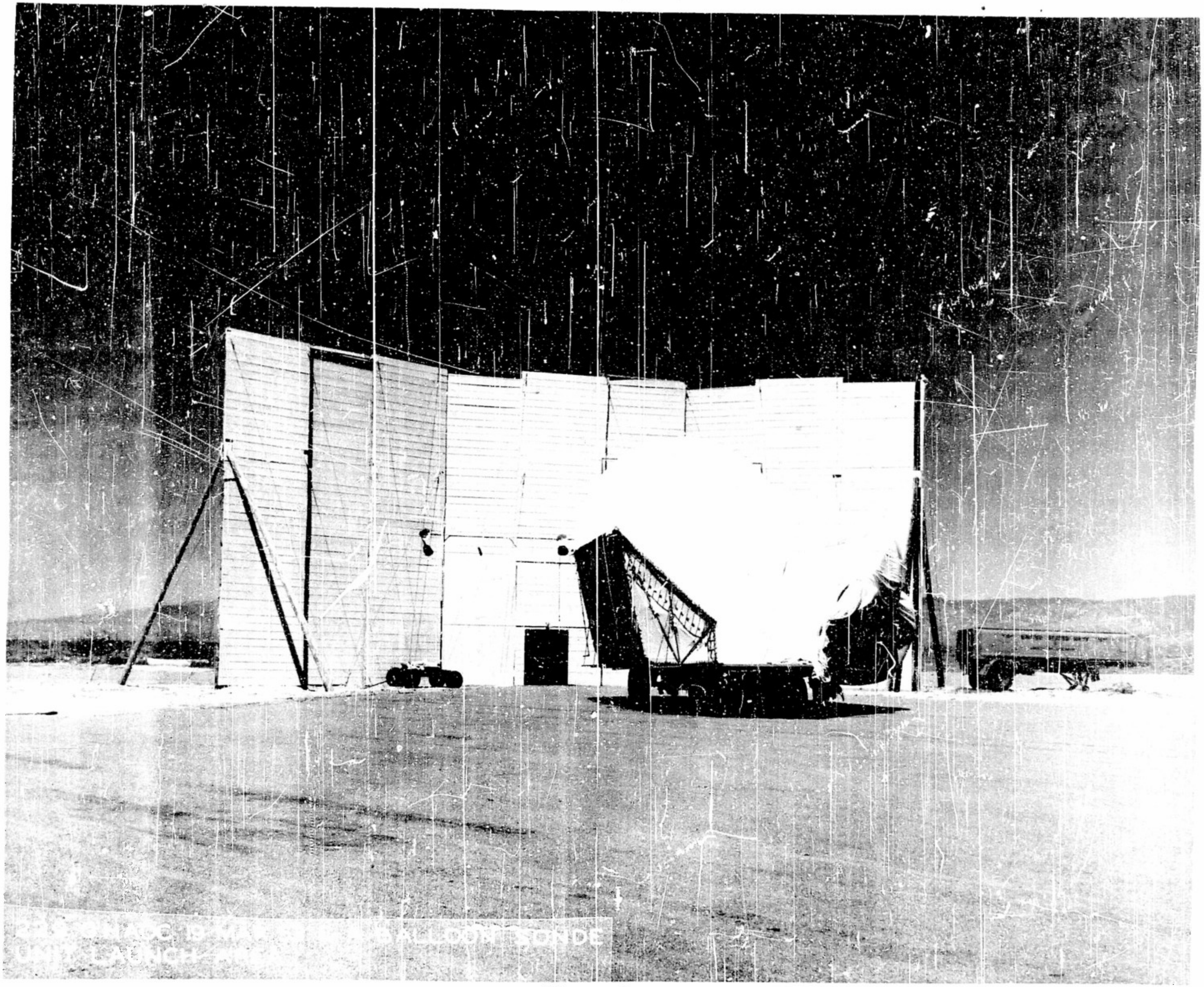
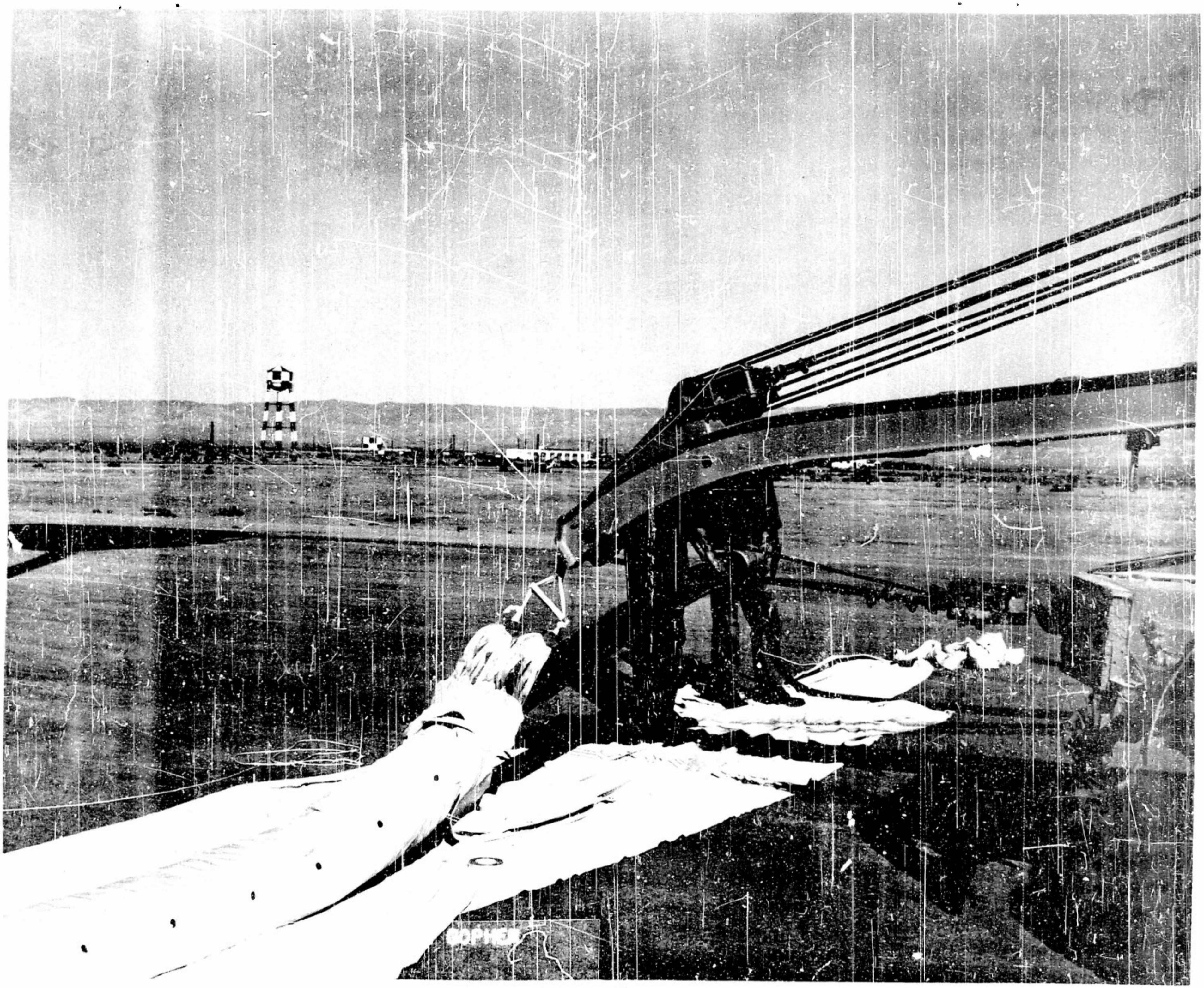


Figure 5



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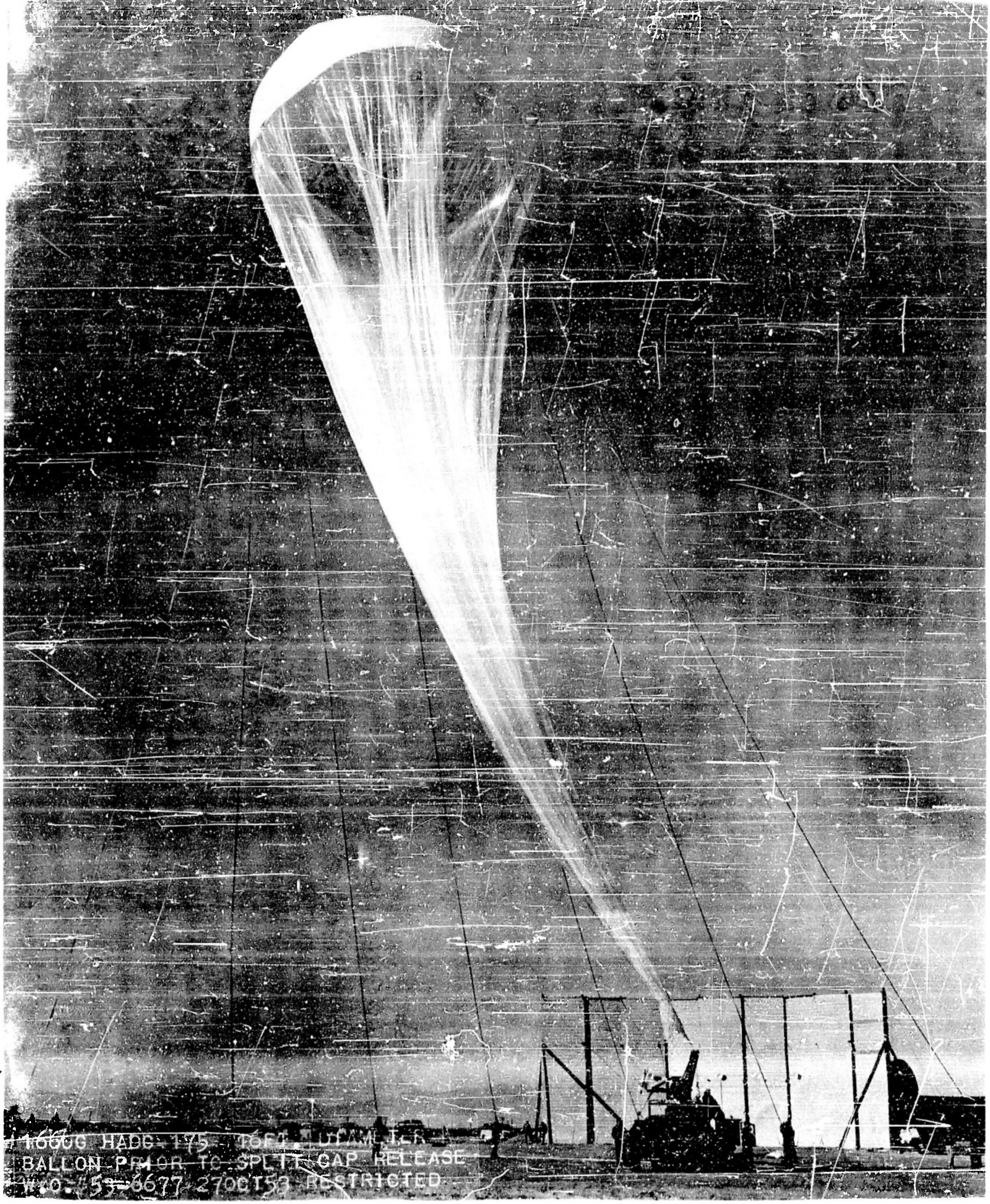
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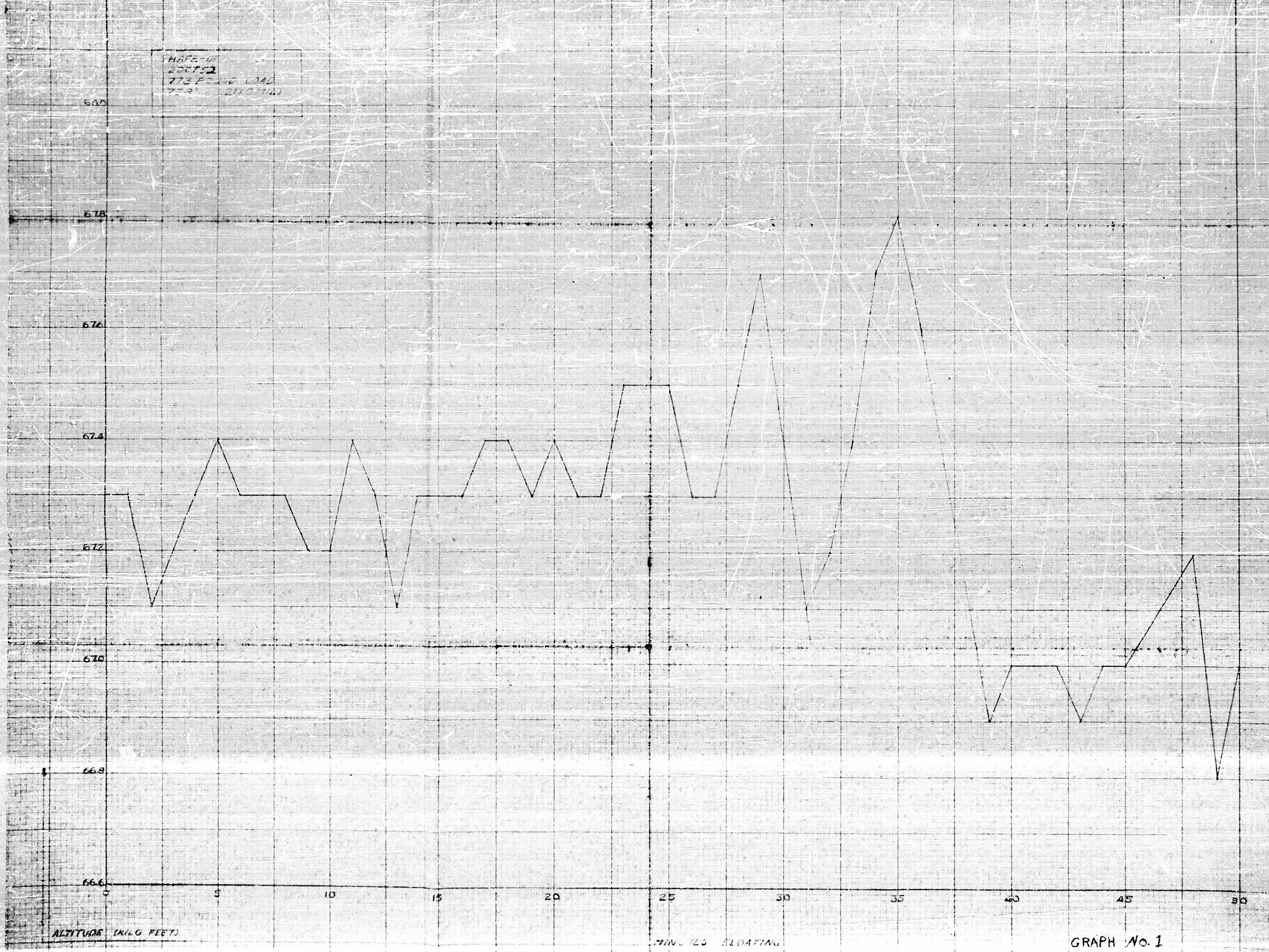
W.O. #53-6677 27OCT53 RESTRICTED

Figure 7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67.0
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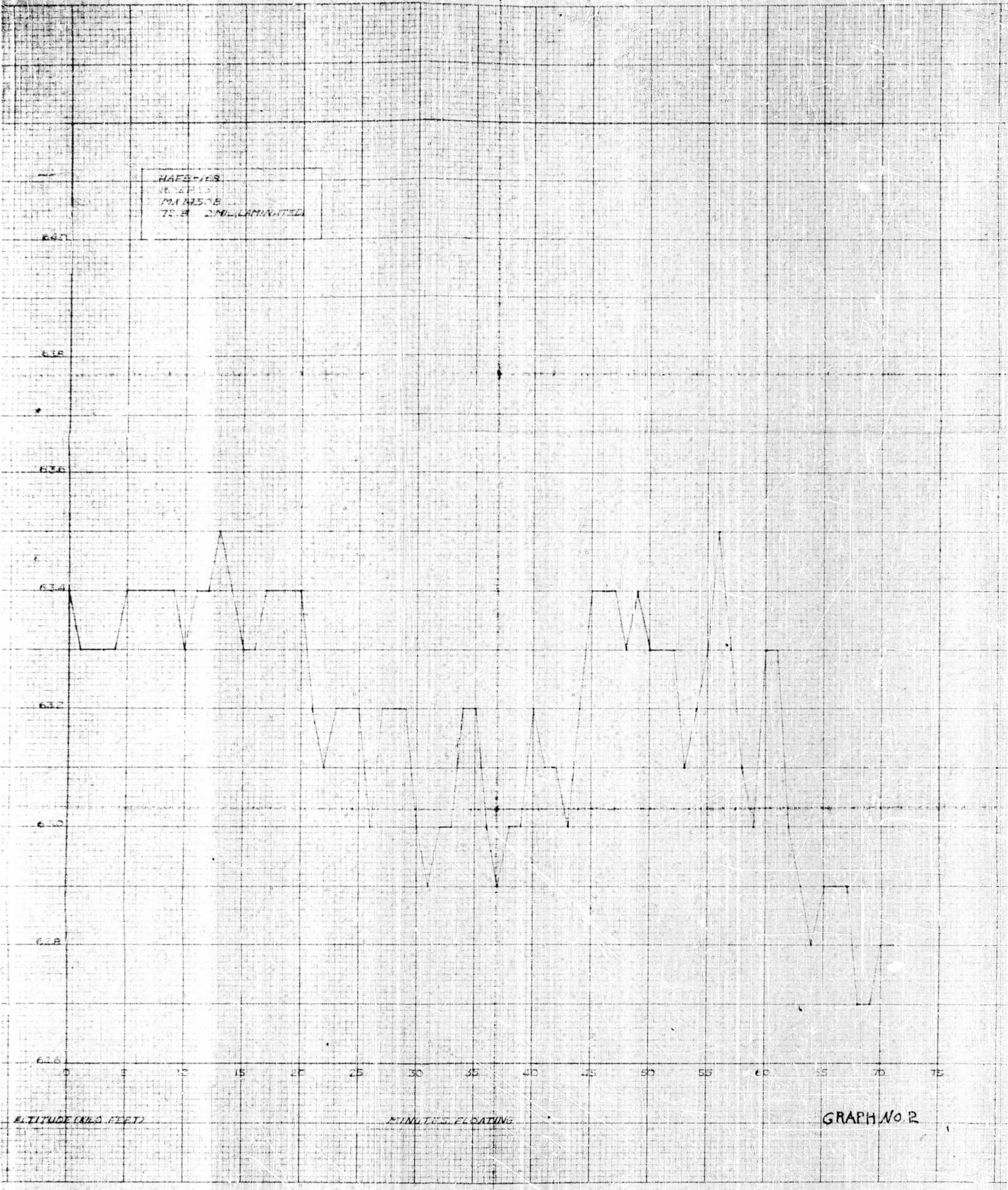
50
MINUTES FLOATING

GRAPH No. 1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ALTITUDE
MINUTES FLOATING

GRAPH NO. 2

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