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FEASIBILITY STUDY OF BALLOON SUSPENSION OF NUCLEAR TEST DEVICES

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ABSTRACT

At the request of the AEC, Sandia Corporation Field Testing Organization flew a 42-foot diameter and a 62-foot diameter balloon to determine the feasibility of using balloons to support test devices at altitudes of 700 to 1500 feet. A 62-foot diameter balloon can fly a 2000-pound payload at 1500 feet altitude in winds of 15 knots.

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INTRODUCTION

In November 1955, the AEC requested Sandia Corporation to prepare a proposal on the feasibility of using a balloon suspension for a full-scale test device (Ref. ETP-WWA-989). The Full-Scale Test Department of the Sandia Corporation Field Testing Organization had flown small balloons for a full-scale test during Operation Wigwam and was familiar with balloons and some of their idiosyncrasies. The Test Department therefore agreed to make a preliminary feasibility study using a Wigwam type balloon, and also one of operational size. This memorandum gives results of experimental flights of these two balloons performed in February 1956 at the Los Lunas Bombing Range.

THE BALLOONS

The smaller balloon was a helium-filled, polyethylene lined, nylon balloon 42 feet in diameter. This type balloon was used in Operation Wigwam as an instrument suspension. It was used in the Los Lunas flights to test experimental guying arrangements and to verify calculations of the various parameters affecting balloon flight.

The larger balloon was a helium-filled, polyethylene lined, nylon balloon of design similar to the smaller balloon, but 62 feet in diameter. It was used for a further verification of calculations and to gain experience in handling a balloon large enough to support a full-scale test device. Tentative specifications provided by AEC called for a minimum payload of 1,000 pounds at a range of height from 700 feet to 1500 feet above the terrain.

Factors Affecting the Use of Balloon Suspensions

The factors affecting the use of balloon suspensions for field tests may be defined as follows:

1. Gross Lift
   The lift measured at the base of the balloon.

2. Net Lift
   The lift remaining when the balloon is supporting a payload at altitude in zero wind.

3. Payload
   The weight of cab, test device, instrumentation, and instrument cable.

4. Guy Line Length
The length of a guy line in a symmetrical configuration of three guy lines.

5. Wind Speed and Direction
The speed and direction of the wind at the balloon.

6. Altitude
The height of the cab above ground zero.

7. Position Error
The horizontal distance a test device moves from a vertical through ground zero.

Interaction of the Factors

Since the speed and direction of the wind cannot be controlled or accurately predicted, it is necessary to adjust the other factors with a view to successful performance of the balloon under a variety of wind conditions. Because of this requirement, the cable configuration chosen for the Los Lunas tests consisted of three equally spaced guy cables, plus a vertical cable (see Figure 1). The three guy cables permit stable flight with minimum cable weight, and they provide positioning control for winds from any direction. This arrangement has been found satisfactory in the field.

The gross lift is the primary consideration for determination of balloon behavior. In general, flight at a low altitude with a small payload and toleration of moderate position errors increases the allowable wind speed. This statement is based on the following considerations:

1. An increase in payload decreases the lift available to counteract wind forces.

2. An increase in size, number, or length of cables likewise decreases the lift available to counteract wind forces.

3. An increase in wind velocity increases tension in the upwind guy cables, increasing the downward component of the tension and decreasing the lift.

4. A change in wind direction can change the downward force due to wind drag by a factor of two. The downward force is minimum for wind directly down one guy, and maximum for wind directly between two guys.

5. Position errors can be reduced by increasing cable tensions, but this in turn reduces the lift.

6. An increase in altitude decreases the lift because of the increased length of the guy and vertical cables. Because of the change in cable angles, an increase in altitude also increases the downward components of the tension in the guy cables so that any increase in wind speed or in positioning tension has a greater effect in reducing the lift.

Test Flight Results

Data on the performance of the operational balloon is given in Figure 2.

Accelerations on Cab

Due to the failure of an accelerometer, little data was obtained. Tests can be conducted in the fall to determine accelerations. It is expected that the cab will experience one g or less.

Expected Wind Velocities

Wind velocities experienced at shot time in past operations are shown in Figure 3.

Equipment for Operational Balloon

Figures 4 through 6 show the size of the balloon and a portion of the equipment used in the tests.

Safety Factors

Since safety is of prime concern, the following safety factors should be incorporated in the operational design:

1. Breaking strength of the vertical cable is to be 300% of the gross lift of the balloon.

2. Breaking strength of each guy cable is to be 150% of the gross lift of the balloon and 400% of its nominal working load.

3. An inherent safety factor is the fact that all cables are under tension considerably minimizing dynamic loading should one cable break.

Using the above safety factors, no cable failures were encountered during the Los Lunas tests.

Further Safety Factors Now Under Study

Two proposed methods of handling the balloon in case of emergency are under consideration as further safety measures. These are:

1. rapid automatic deflation of the balloon to lower it to the ground;
2. release of the balloon, and parachuting of the test device to the ground.

CONCLUSIONS

The 62-foot operational balloon tested, which had a free lift of 5500 pounds, flew a 2000-pound payload at 1500 feet altitude in a wind of 15 knots from any direction with a position error of less than 30 feet and an altitude error of less than one foot. The balloon should be able to fly in higher winds at a lower altitude or with a smaller payload. The Los Lunas tests indicated a drag coefficient for the balloon of approximately 0.4. Using this drag coefficient, calculations show the same balloon should fly a 2000-pound payload at 700 feet altitude in winds in which the gusts do not exceed 30 knots. Extended flight at greater than 20 knots may result in the development of slow leaks. Reinforcement of the balloon may eliminate this problem. The calculations also indicate the balloon will not maintain stable flight at 1500 feet altitude with a 2000-pound payload if wind gusts go above 18 knots.

On the basis of wind speeds during previous shots, it would have been possible to fly the test devices at 700 feet for 90% of the previous test shots, or at 1500 feet for approximately 65% of the previous shots.

On the basis of experimental flights and safety factors, the probability of balloon failure or the balloon's breaking away from its moorings appears negligible, though provisions for emergency lowering of the cab are desirable and must be designed.

RECOMMENDATIONS

1. The Balloon

   In view of the successful performance of the present balloon design, it is recommended that this design be used. The following minor changes should be made, however:

   a) A larger filling tube should be used for faster inflation. The inflation time should be one hour or less.

   b) The filler tube should be located nearer the center of the balloon to increase the filling rate by preventing its being pinched in the folds.

   c) Tests of the ultimate strength of the base of the shroud and possible modification of the base fitting should be investigated.

d) Large tie patches for hold-down during high winds should be installed.

2. Ground Zero Installation

A desirable ground zero installation should include:

a) A roller chock mounted flush with the ground with a limited movement sheave located underground.

b) A 100-foot x 100-foot pad of stabilized area for balloon inflation.

c) Padeyes located in the area for inflation and deflation of the balloon.

d) An outlet for remote control of all the winches.

3. High Wind Procedure

In the event of a cancellation or of high winds after the balloon is flying, it is recommended that the following steps be taken:

a) The cage and unit be brought down to ground zero by remote control.

b) The firing party disarm the test unit.

c) Flight personnel then enter and secure the balloon.

4. Winch Installation for 2000-Pound Payload Balloon

It is recommended that winches be located at the farthermost anticipated guy lengths, i.e., at 3000 feet from ground zero. For shorter guy lengths, a snatch block can be installed at the desired position. Each winch should be installed through an overhead hatch in a concrete bunker which is partly above ground. The bunker in combination with a sloping earth fill should withstand overpressures on the order of 20 psi.

The winches should have the following features:

a) 15,000 pounds stalling load for guy cable winches and 25,000 pounds stalling load for the vertical cable winch.

b) Remote control provisions.

c) Operate from 220V-3 phase alternating current.

d) Level wind.

e) Hermetically sealed plug-in relays if possible.

f) Slack cable switch.

g) Continuous strain readings on cables with remote indicators.

h) Remote reading footage indicator.

i) Self-locking drum.

j) Forward and reverse speed of 60 feet per minute.

k) 1700 feet of 1/2-inch cable capacity on vertical cable winch.

l) 700 feet of 3/8-inch cable capacity on guy-line winches.

m) Voltage test panel.

5. Cables

The cable used for balloon operations should be aircraft cable because of its small weight-to-strength ratio. The vertical line should be 4700 feet in length and the guy lines should be 3700 feet in length.

6. Rigging

It is recommended that all cables be fitted with swivel safety hooks, and be tested to 75% of ultimate strength of the cable.

7. Instrument Cable

The instrument cable must be capable of supporting its own weight. Its weight should be kept to a minimum. The instrument cable can be controlled by a car moving along a guided path or put on a separate winch requiring slip rings.

8. Control Point

The proposed console layout for the control point is shown in Figure 7. This console uses a closed circuit television screen. The television camera at ground zero should be provided with three interchangeable lenses to accommodate the three different probable altitudes of flight.

9. Cab

It is recommended that the cab for the test device be designed jointly by the user and the balloon suspension personnel.

10. Operational Procedures

The following procedures should be followed during an operation:

a) Installation and checkout of the device in the cab prior to balloon inflation.

b) Balloon inflation followed by marriage of the balloon to the cab.

c) Withdrawal of inflation personnel from the test area.

d) Arming of the test device by the arming party, followed by withdrawal of the arming party.

e) Raising of the test device from the control point.

f) Firing of the test device from the control point.

Estimated Costs

The cost for winches, bunkers, and all other necessary equipment is estimated at $200,000 with the following breakdown:

Winches 4 at $15,000	$ 60,000
Bunkers for winches 4 at $15,000 - $20,000	80,000
Instrument cable winch, 1 at $5,000	5,000
Wire rope and fittings	2,500
Instrument cable	3,000
Cab	5,000
Ground Zero Installation	7,000
Cable laying	15,000
Balloon shroud and liner	5,000
Helium	1,500
Winch installation	2,000
Control point installation	5,000
	$191,000

Of the above items, $19,000 worth would be expended during each test. The above estimate assumes the loan of Navy helium equipment capable of holding two hundred fifty thousand cubic feet of helium.

DEPARTMENT 5230
A. D. THORNBROUGH

H. G. LAURSEN

Case No. 666.09
April 4, 1956

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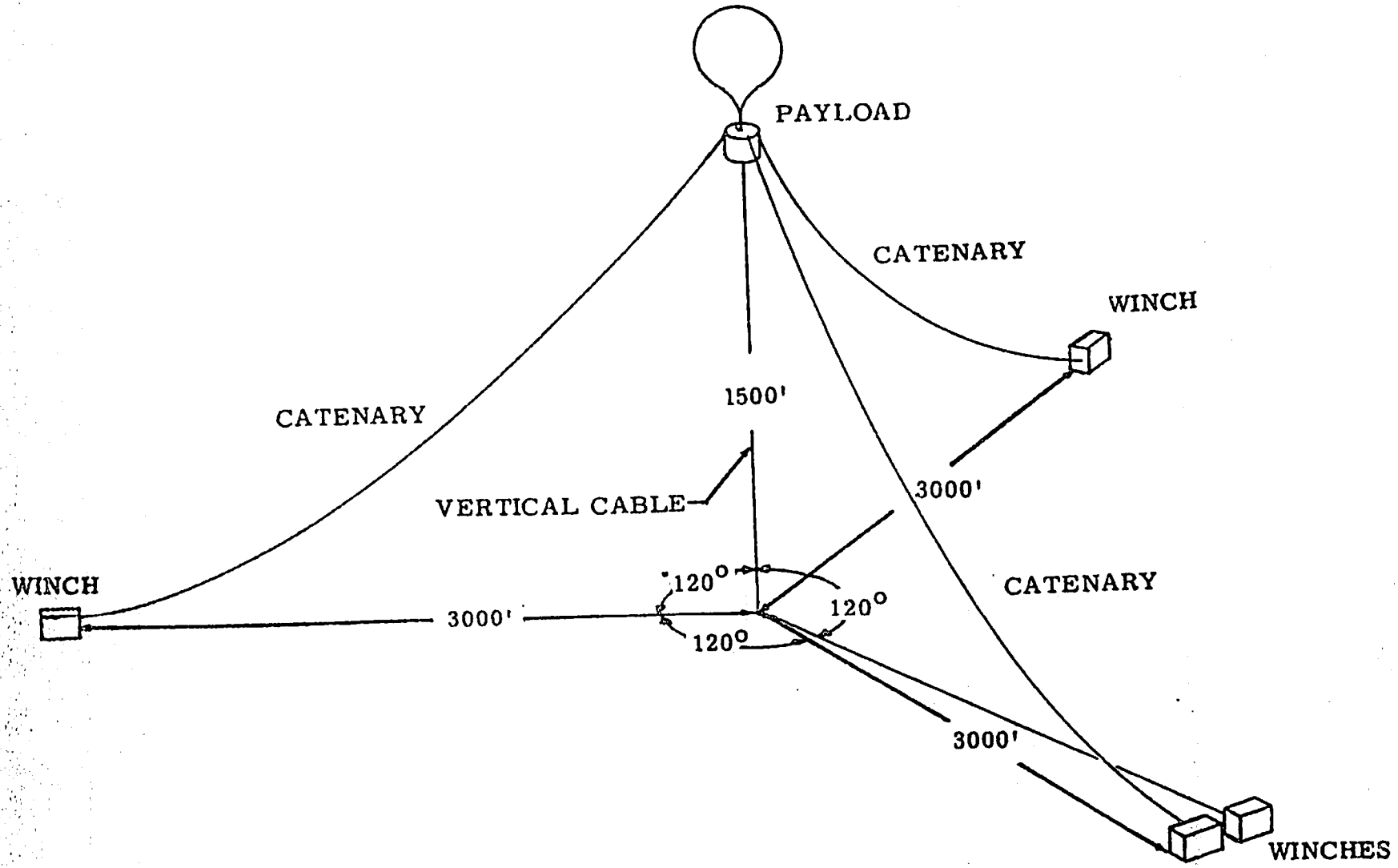

BALLOON CABLE CONFIGURATION

FIGURE 1.

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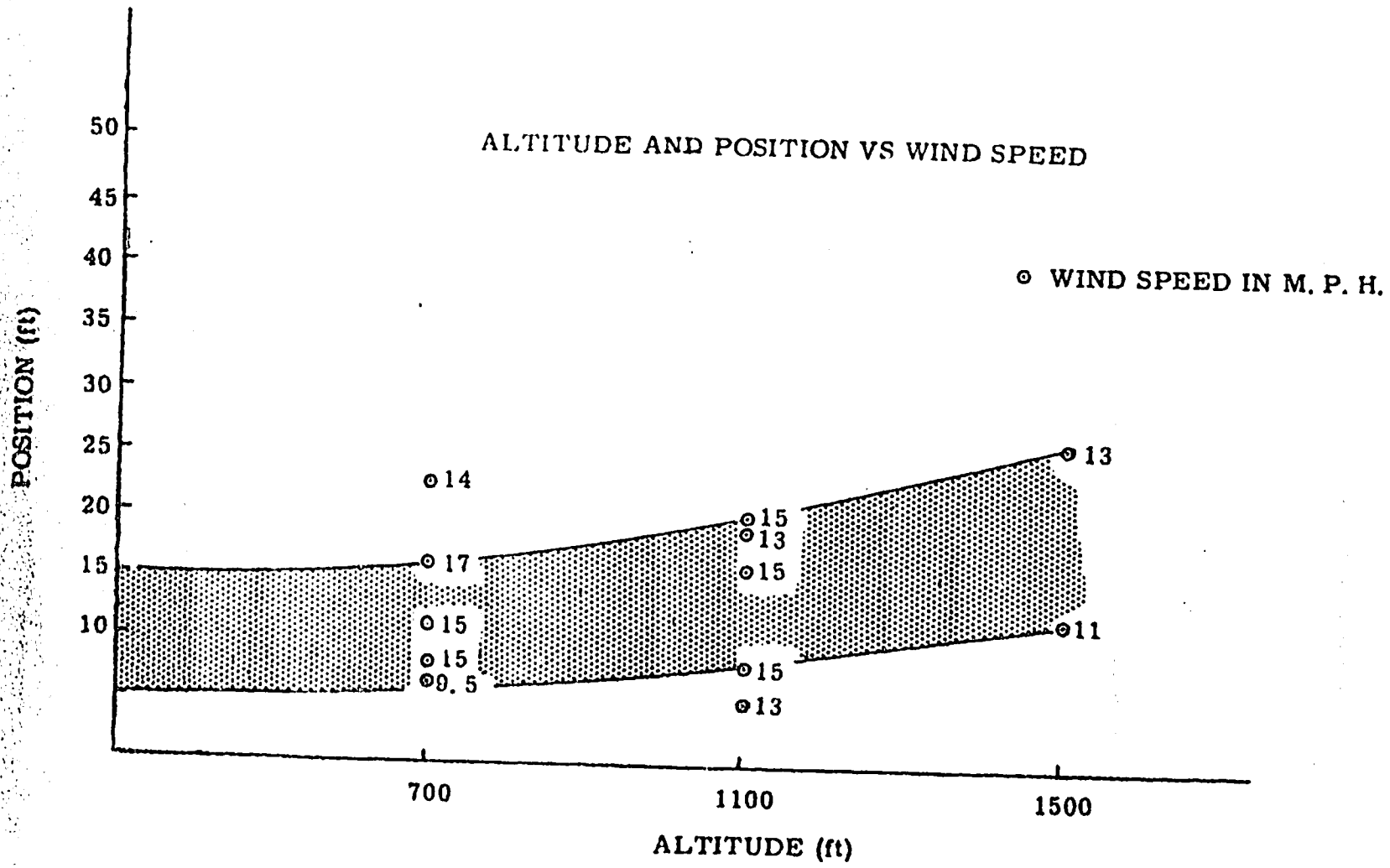

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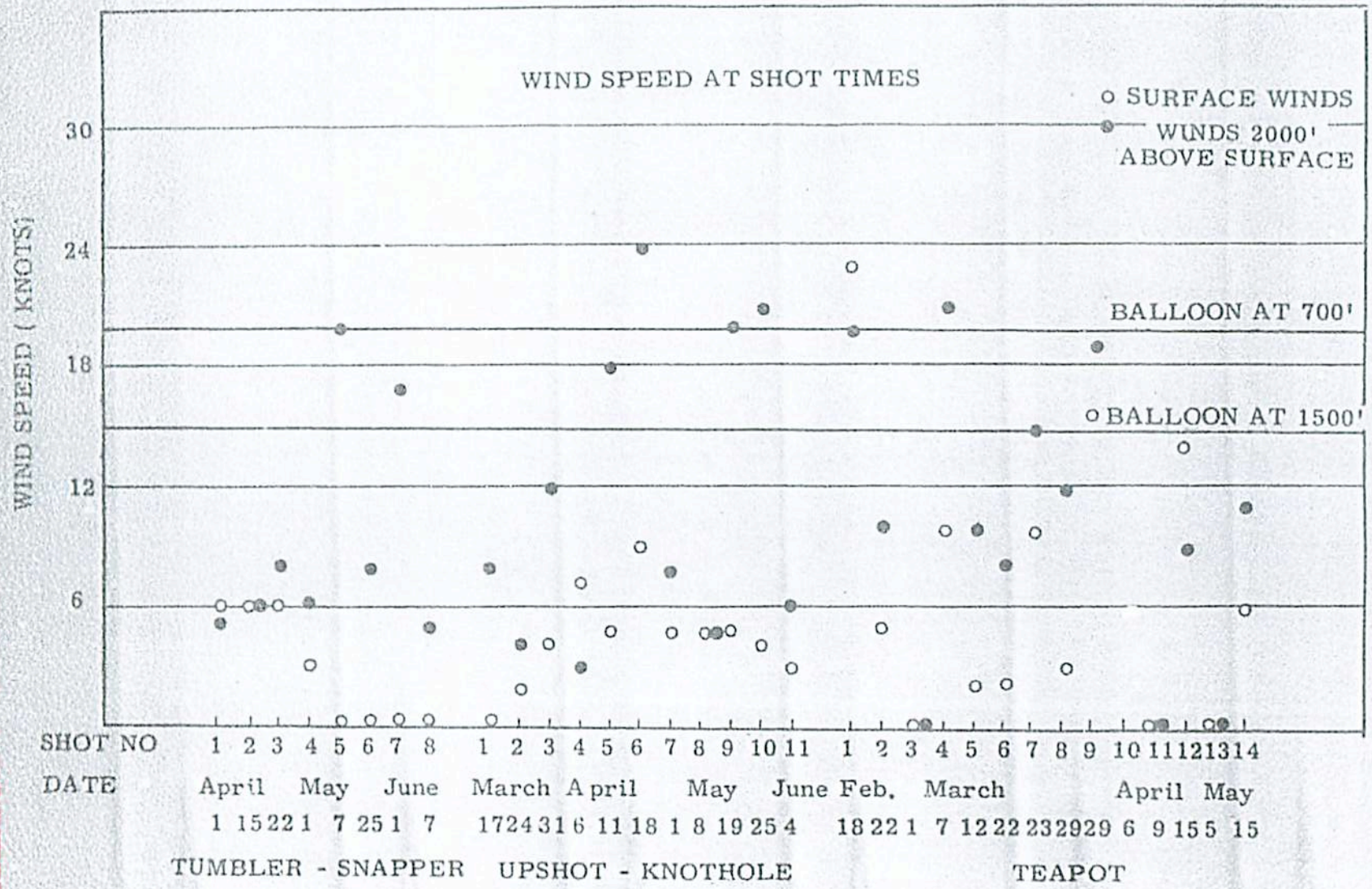

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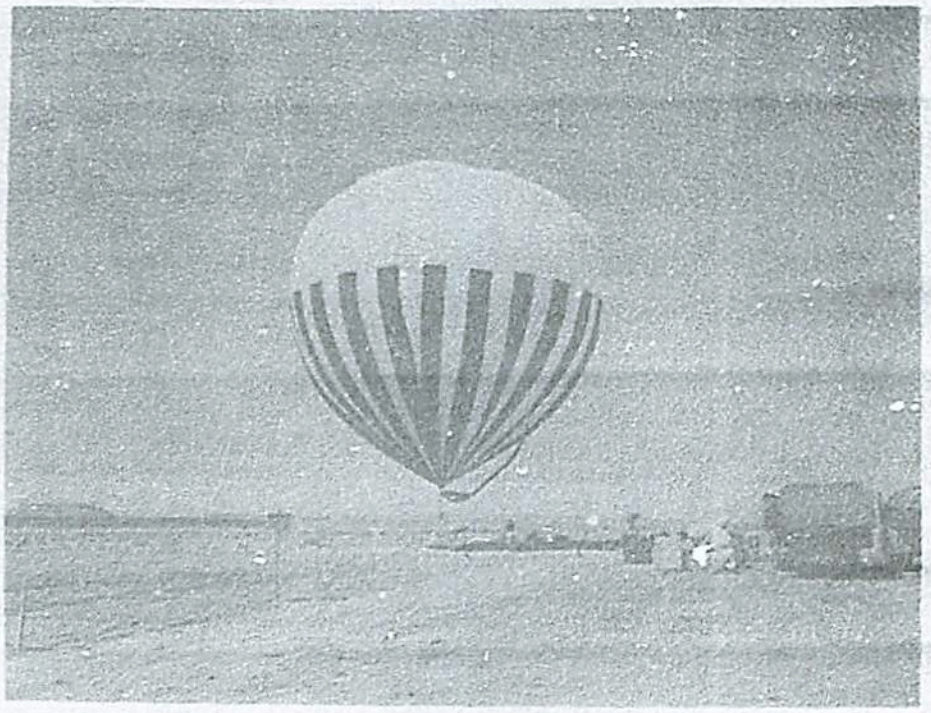

Fig. 4 - Operational Balloon at Ground Zero Prior to Flight

Fig. 5 - Guy Cable Winch

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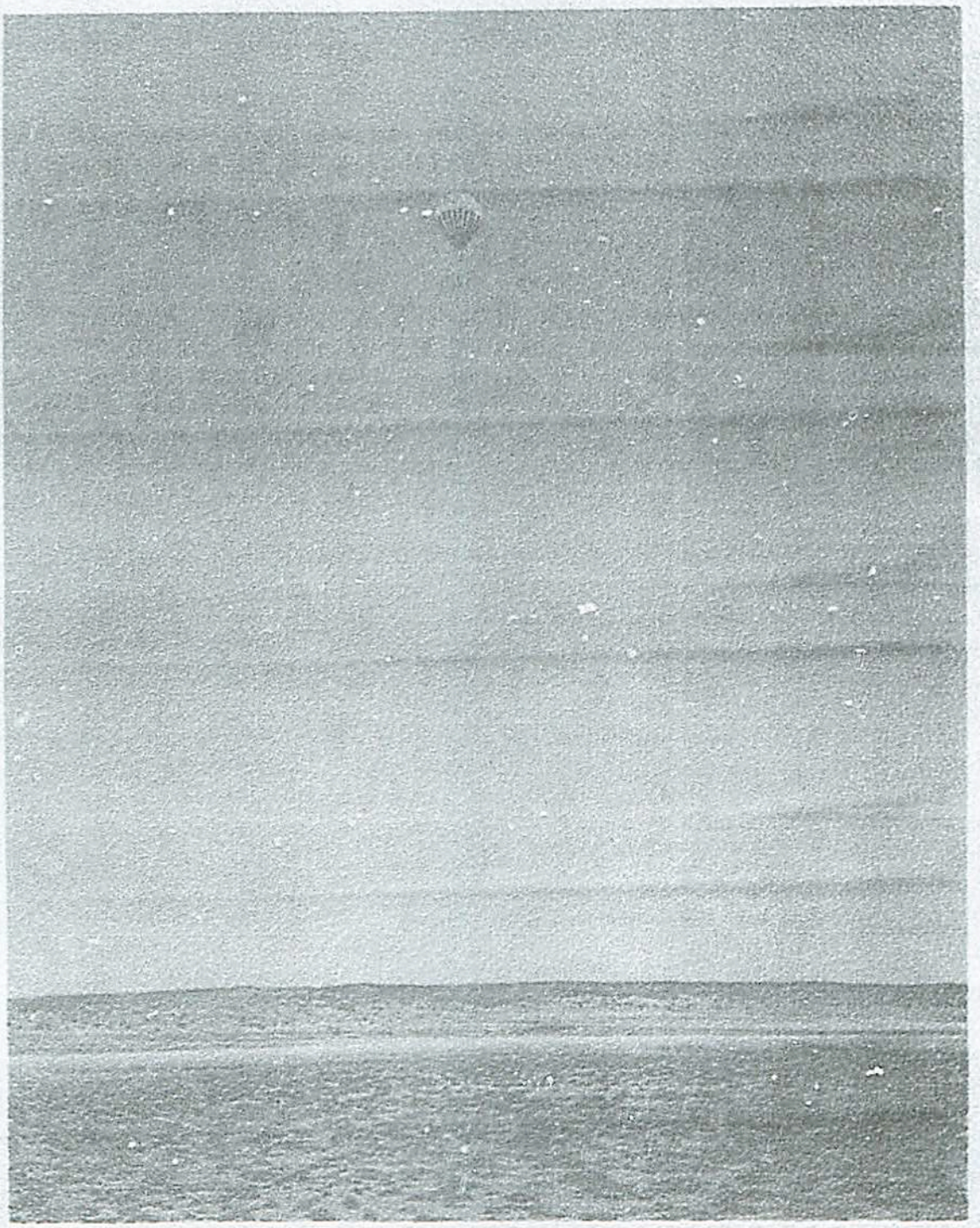

Fig. 6 - Operational Balloon at 700 Ft. Altitude

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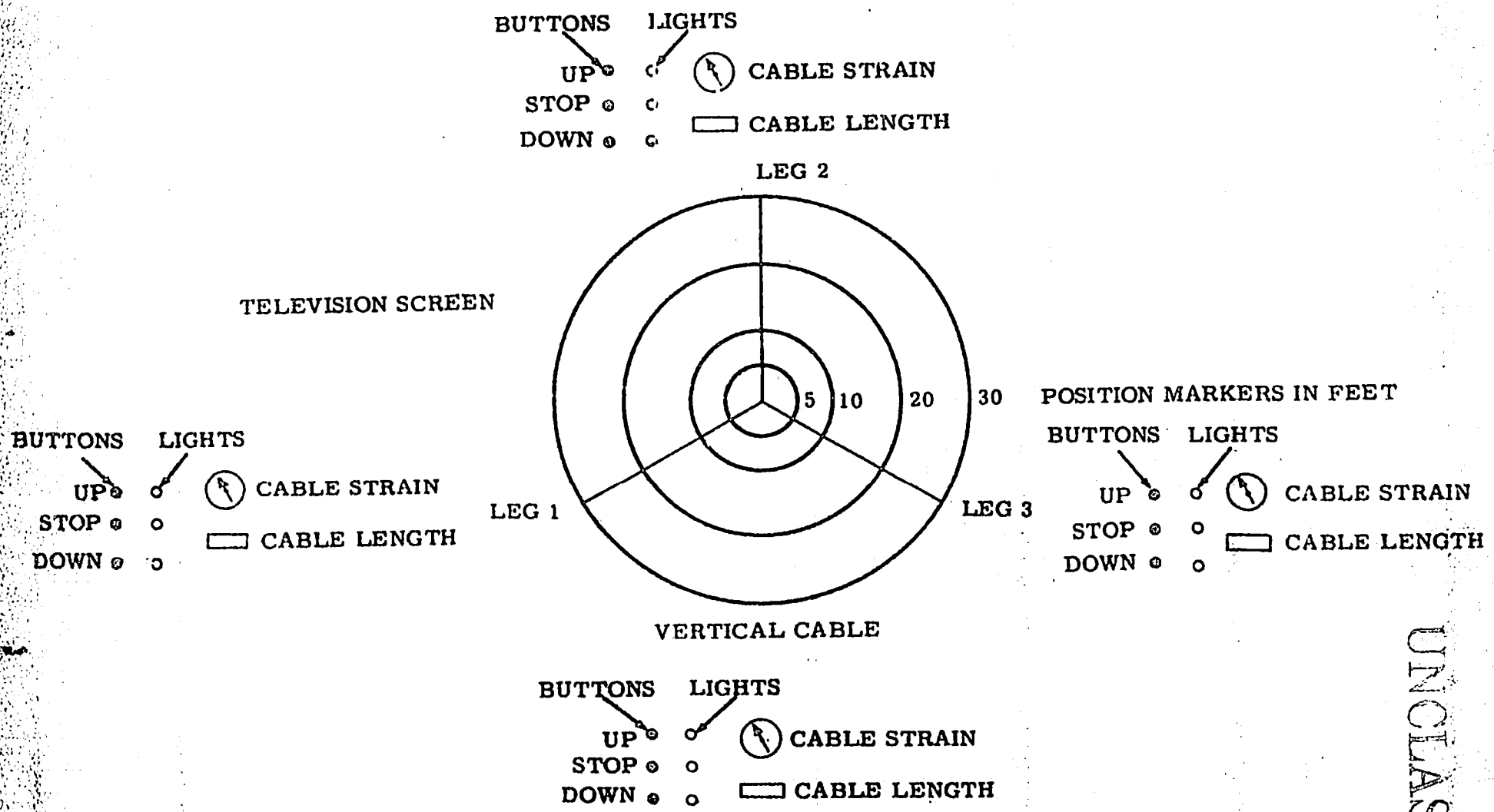

PROPOSED CONSOLE LAYOUT IN THE CONTROL POINT

FIGURE 7.

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