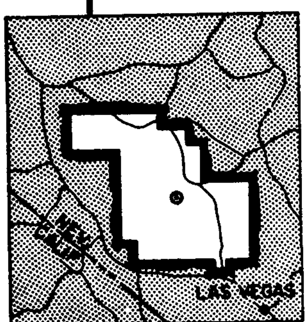
ITR-1469

AEC Category: BIOLOGY AND MEDICINE
Military Categories: 5-50 and 5-90

PRELIMINARY REPORT

OPERATION PLUMBBOB



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Project 33.3

TERTIARY EFFECTS OF BLAST—DISPLACEMENT

Issuance Date: December 20, 1957

CIVIL EFFECTS TEST GROUP

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Operation PLUMBBOB Preliminary Report

Project 33.3

TERTIARY EFFECTS OF BLAST — DISPLACEMENT

By

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Albuquerque, New Mexico

September 1957

ABSTRACT

The objective was to determine the velocity and distance of translation of anthropomorphic dummies and equivalent spheres caused by blast winds. The primary technique for recording the movement of these objects was photo-triangulation. Analysis of the films obtained thereby gave the velocity and distance in the case of shot 1. In shot 2, the field of view was obscured by smoke (perhaps dust too) before any motion could be recorded by the cameras. The secondary technique (applicable to certain of the equivalent spheres) was to have the spheres impelled into missile traps. The resultant penetration provides a means for determining the velocity at the time of impact. Analysis of the results from both the primary and secondary techniques is expected to provide some of the information identified in the objective.

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Reynolds Electrical and Engineering Co., Inc.
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Kirtland Air Force Base
Indian Springs Air Force Base
Sandia Corporation

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ILLUSTRATIONS

TABLES

Chapter 1

INTRODUCTION

1.1 OBJECTIVES

The primary objective of Project 33.3 was to determine the velocity and distance of translation of anthropomorphic dummies caused by blast winds. A secondary objective was to measure the displacement of particular spheres, some of which were subjected to the same conditions of blast as the dummies and some exclusively to winds within a shelter. Data from these tests will provide information interrelated with that of the study of displacement of biological targets (Project 33.1, ITR- WT- 1467) and with that of the study of missiles resulting from blast (Project 33.4, ITR-1470).
WT-

1.2 BACKGROUND

Results of tests conducted in Operation Teapot[1] indicated that for conditions in which thermal and radiation hazards were prevented, but in which overpressure and winds were present, the effect of the winds apparently was of the greater significance. Following Operation Teapot, experiments conducted at the Lovelace Foundation[2] gave results which corroborated the importance of the winds, if translation resulted therefrom, even if the overpressure was such that no biological damage was caused by it. It is understood that for biological damage to result, translation must include the high accelerative or the high decelerative phase.

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Chapter 2

PROCEDURE

2.1 PRESSURE INSTRUMENTATION

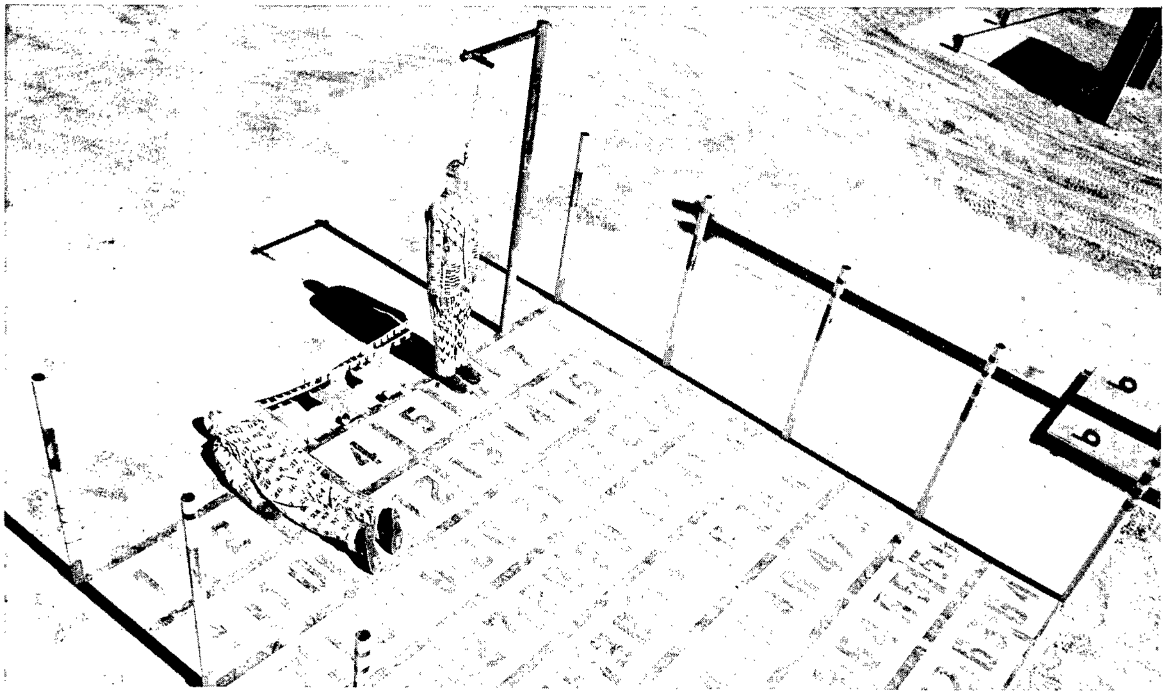
For the particular location at which the dummies and/or the spheres were subjected to blast, the static and dynamic pressures were obtained from the mechanical self-recording gauges provided for Project 33.2 and several other projects of other programs. Installation and operation of these gauges were the responsibility of the Ballistic Research Laboratories (ITR-1501).

2.2 TECHNIQUE OF PHOTO-TRIANGULATION

The basic scheme was to record photographically the path of movement of the object (dummy or sphere) by two motion-picture cameras mounted such that their lines of aim intersected at about 90 deg. In addition, the background common to both cameras was a grid of identified squares (Fig. 2.1). With the cameras operating at equal speeds and started simultaneously, the photographic records provided a means of matching frames of the same instant and thereby fixing the position of the object in space with reference to the background grid. Two GSAP Cameras operating at 64 frames/sec were mounted on each of the two camera towers thereby providing two spares (Fig. 2.2). The plates on top of the towers to which the cameras were fastened were 18 ft above the grid surface, inclined downward 40 deg and oriented at 45 deg in azimuth with respect to the bearing from Ground Zero (GZ). This arrangement was expected to give the best coverage and the most accurate triangulation. A particular event, such as the first appearance of the bomb flash, can be used to index the several photographic records with respect to each other. The motion-picture photography was provided ~~by~~ Edgerton, Germeshausen and Grier.

In addition to the grid, a very important requirement for photography is the dust stabilized area adjoining the grid on both sides and

Each of three events, the bomb flash, the arrival of the shock, and the arrival of the negative phase, was used



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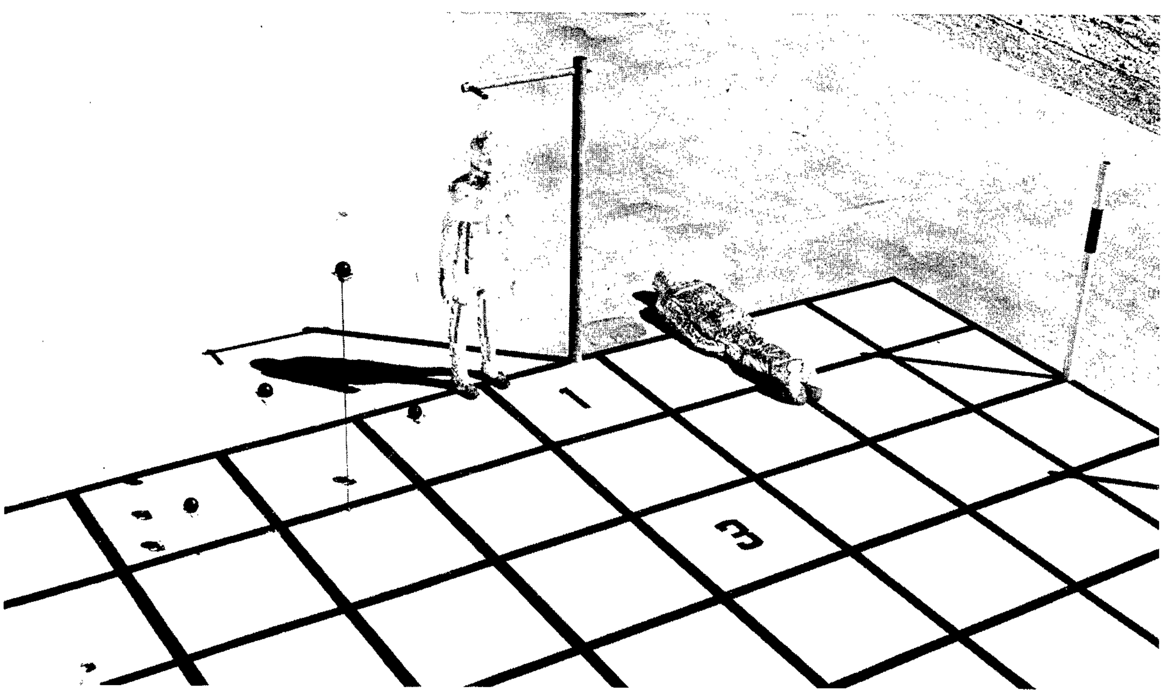


(b)

Fig. 2.1—Views from camera tower showing dummies and spheres. (a) Shot 1, without aluminum foil. (b) Shot 2, with foil.

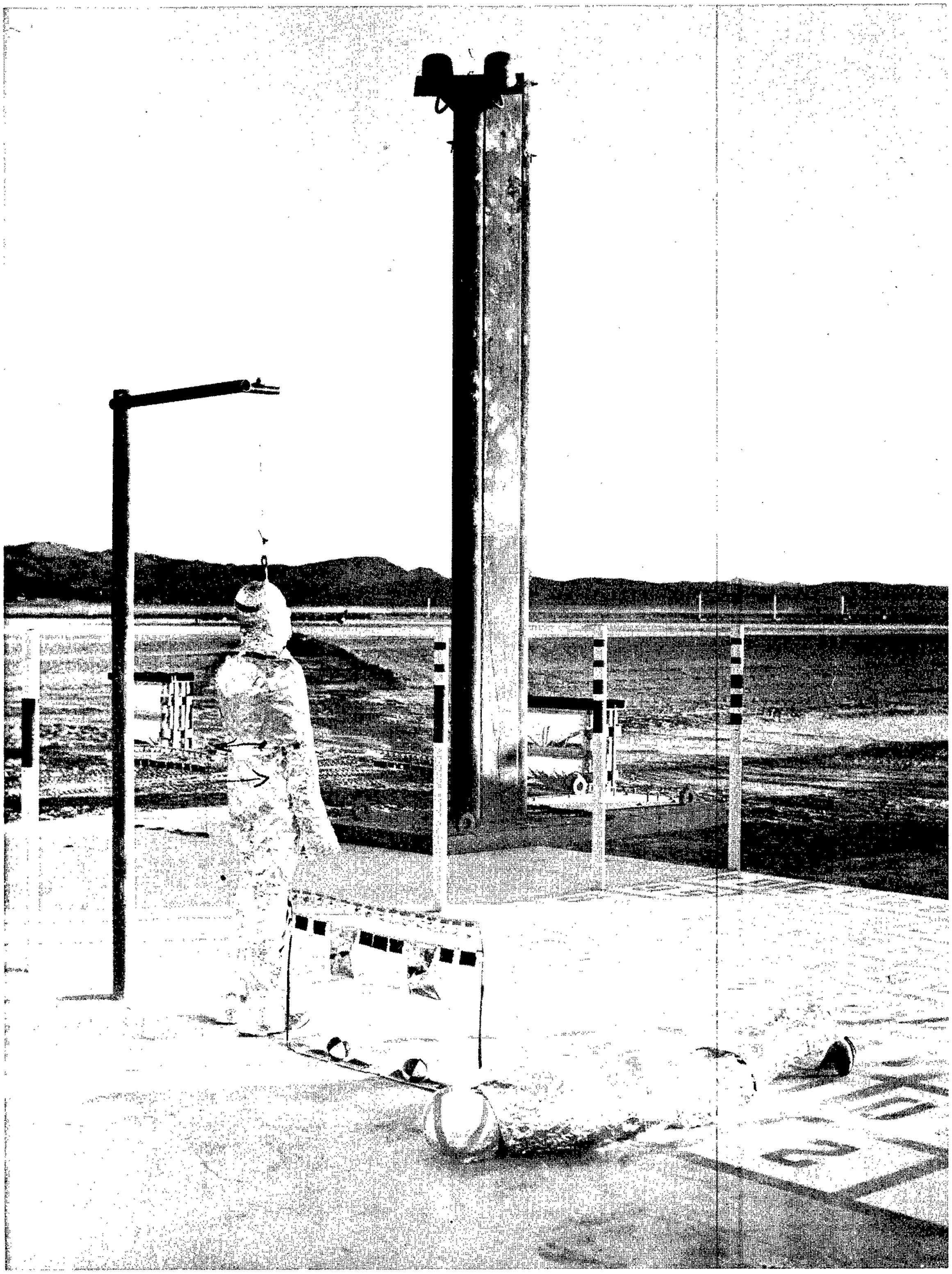


Fig. 2.2—One of two camera towers, showing two cameras mounted under protective hoods.

on the edge toward GZ. In actual construction the grid and the stabilized area were built as a unit (Figs. 2.3 through 2.6). The use of concrete for stabilization was recommended by personnel who experienced difficulties with other materials in earlier operations. The dimensions of the stabilized area were determined as shown in Appendix 1.

2.3 MEASUREMENTS

2.3.1 Free Flight

In each instance where a test object was moved through space by the blast, the coordinates of the final position with respect to the initial position were recorded.

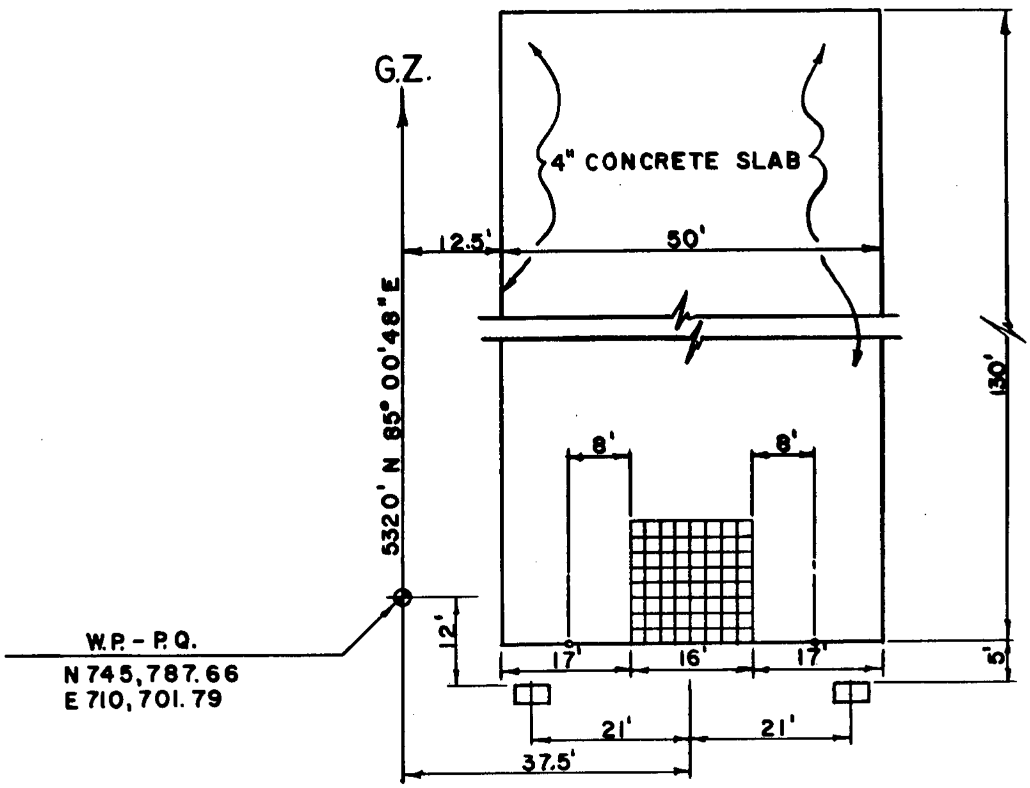
2.3.2 Flight Terminating in Penetration

In those instances in which equivalent spheres were translated into Styrofoam,[1] the resulting penetration and the previous calibration ~~will provide~~ provided data for determining the velocity at the time of penetration. With several different initial positions and corresponding penetrations, ~~a trajectory~~ for a particular equivalent sphere might be constructed. the velocity-displacement history

2.4 TEST OBJECTS

2.4.1 Dummies

Two anthropomorphic dummies (Fig. 2.7) were used in each of two detonations, shot 1 and shot 2. This type dummy is the 50 percentile, weighing 165 pounds (169 dressed) and measuring 5 ft 9 in. in height.[1] The distribution of weight among the components of the body and the construction of the joints simulate the human body to a high degree. One dummy was used in a prone position in both detonations. The prone position was face down, head toward GZ, arms against body, and legs closed together. The other dummy was used in the upright position with his back to GZ in both detonations but with major differences for each/detonation (Figs. 2.8 and 2.9). In shot 1 the dummy had loose joints, representing full relaxation, and was suspended from its head with negligible weight on its feet (less than 3 pounds per foot). In shot 2 the upright dummy was stood on its feet with joints tightened enough to permit it to stand with no support. A very light string (10 pounds breaking strength) was tied from an overhead support to the dummy's head to hold it in the zone of stability against natural gusts of wind which might have toppled ~~him~~ it before H-hour. With this arrangement the full weight of the dummy was supported on its feet. As an



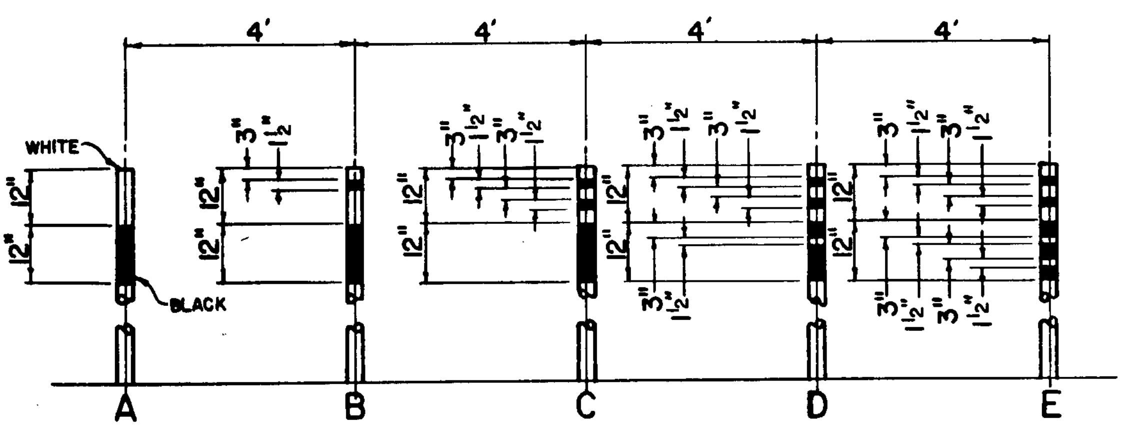


Fig. 2.3—Concrete pad and photography grid (shot 1).

(17)

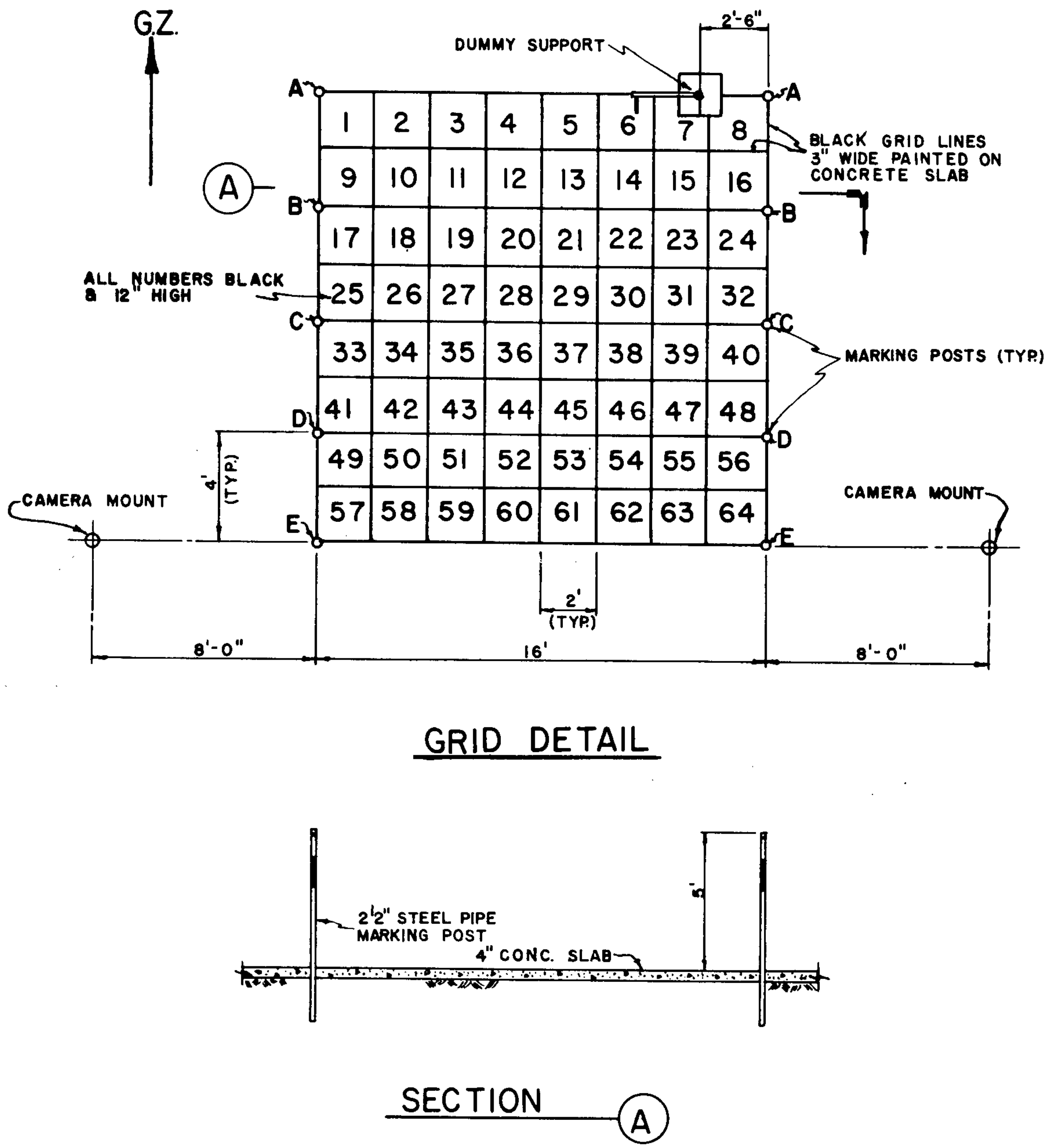


Fig. 2.4—Details of the photography grid showing the positions of the camera towers and the marking posts (shot 1).

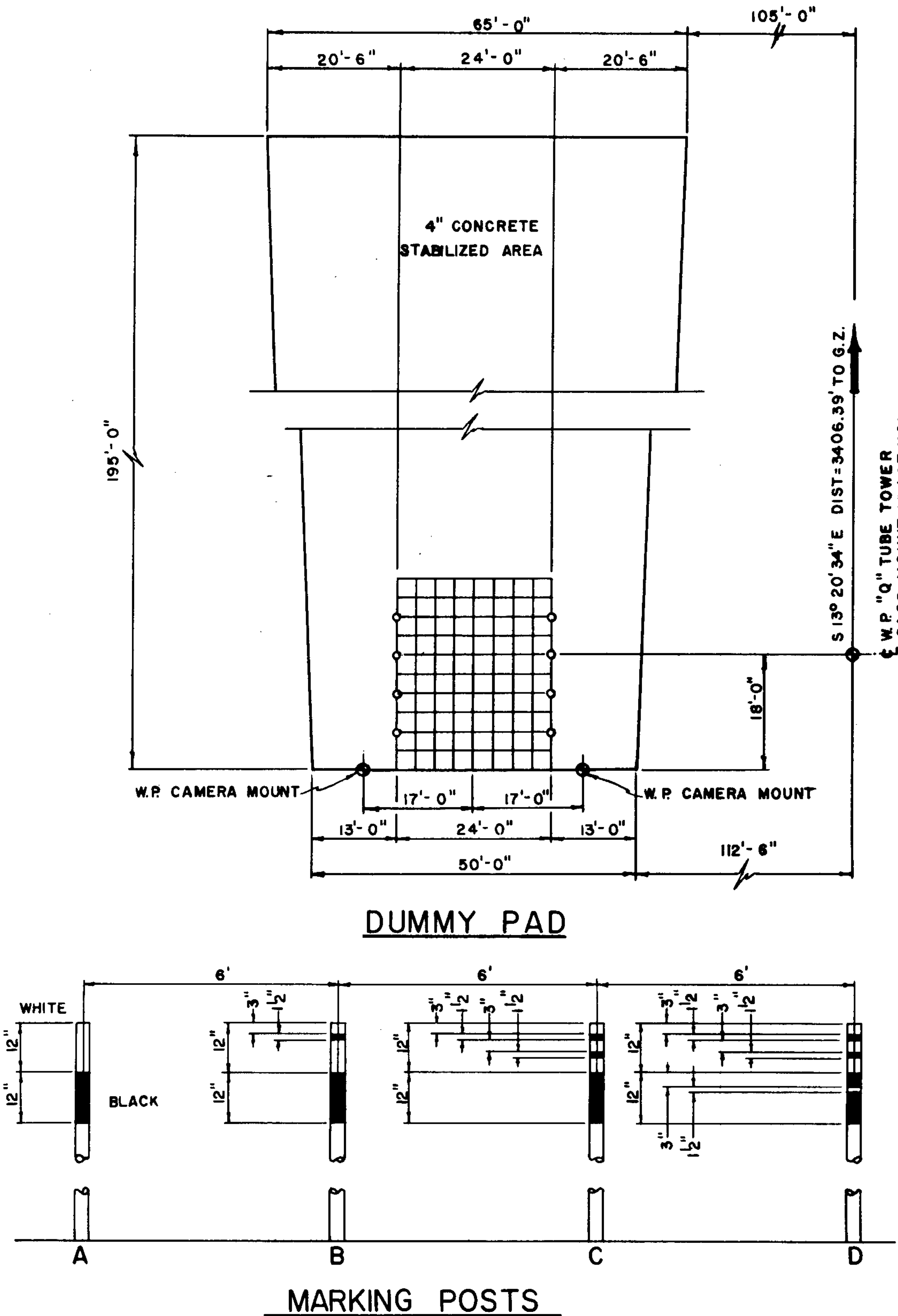
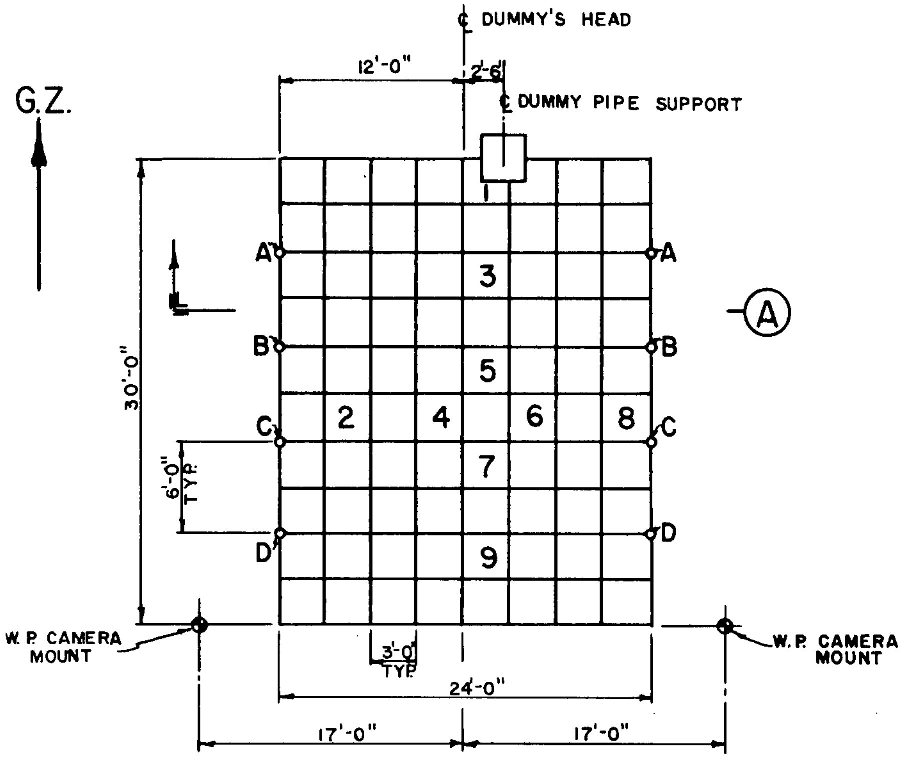
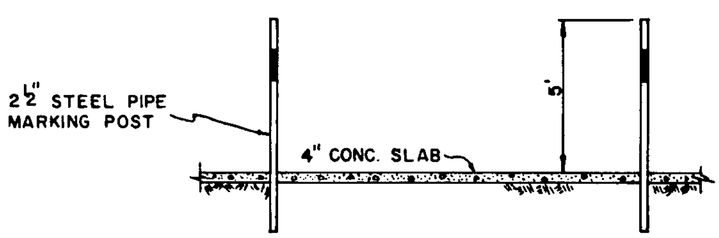


Fig. 2.5—Concrete pad and photography grid (shot 2).

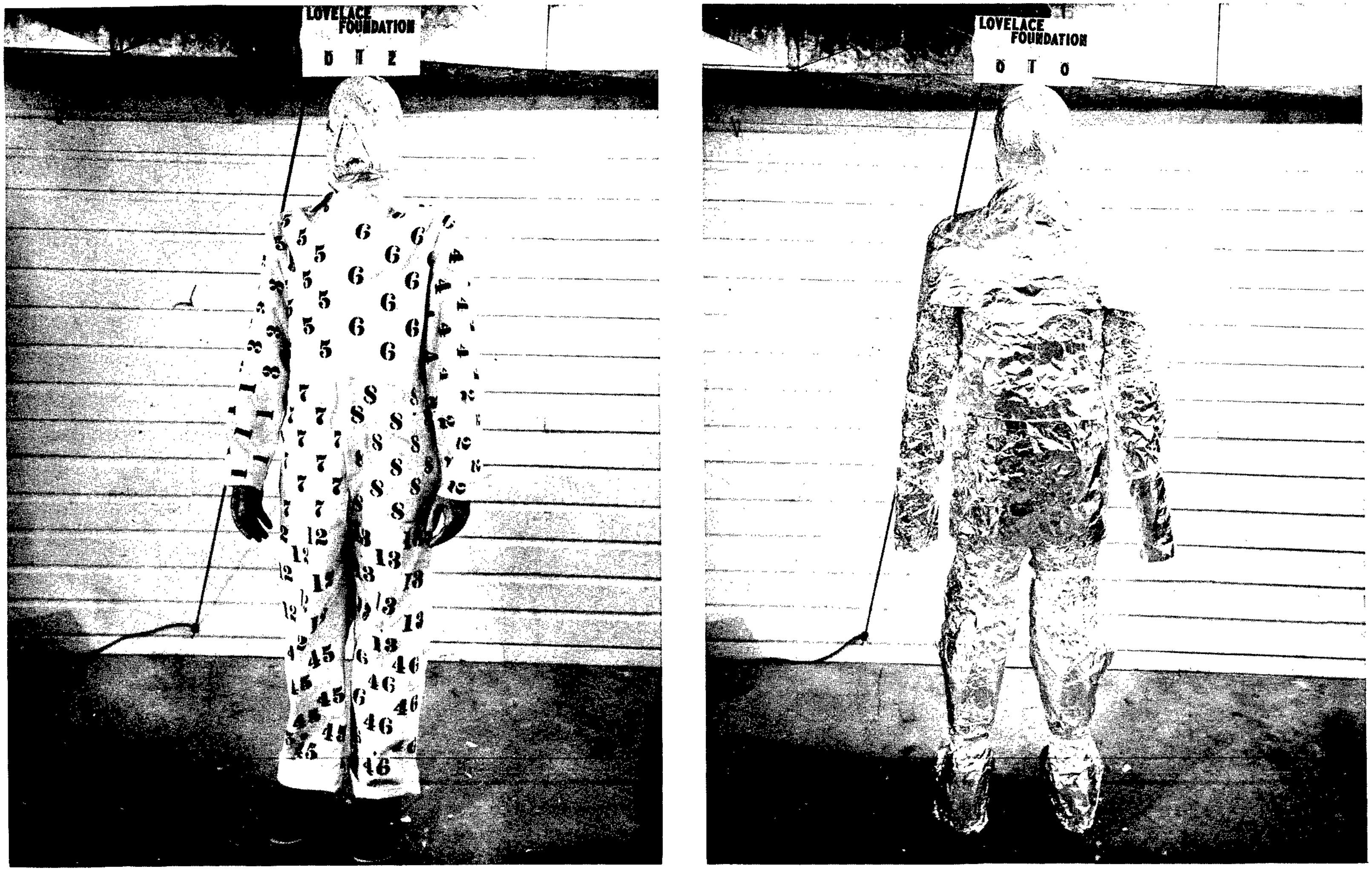


GRID DETAIL



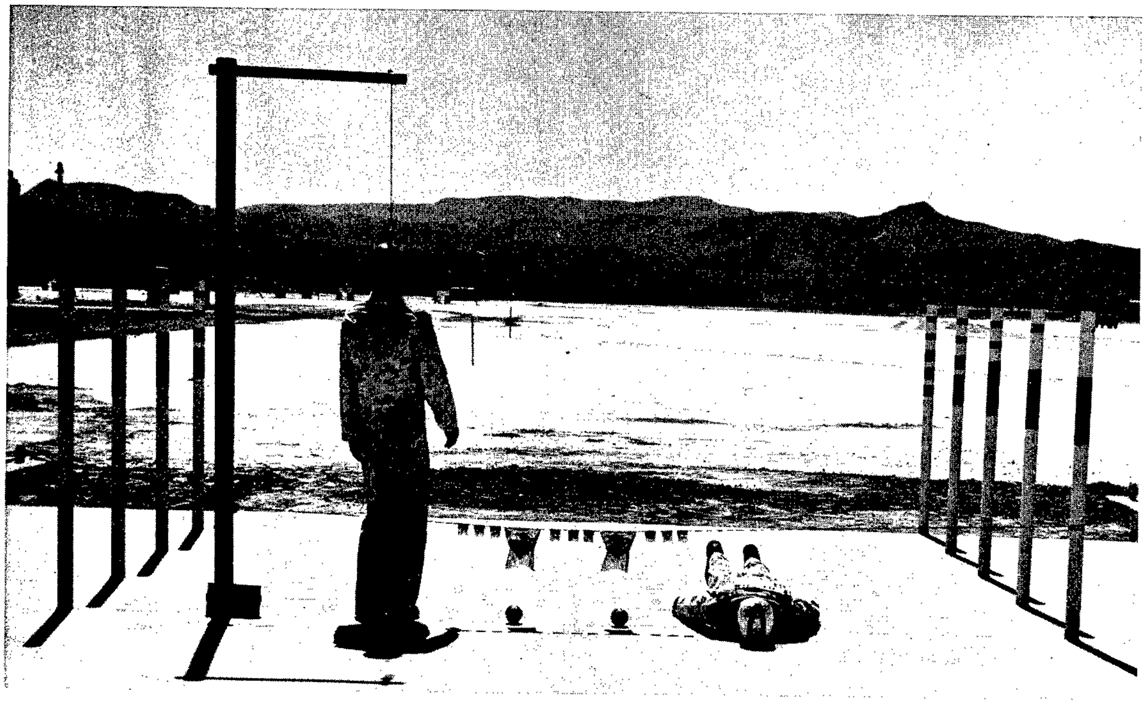
SECTION Ⓐ

Fig. 2.6—Details of the photography grid showing the positions of the camera towers and the marking posts (shot 2).



(a) (b)

Fig. 2.7—Front and rear views of dummy. (a) Front view showing method of identification of the various parts of the body. (b) Rear view (toward GZ) showing protective aluminum foil.



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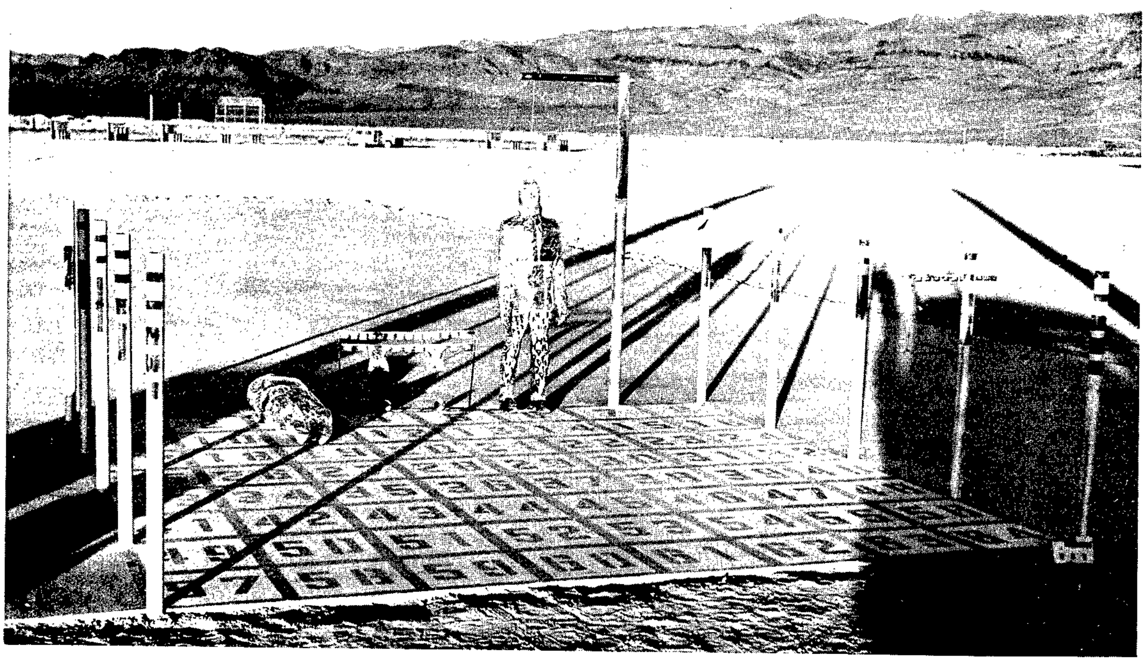
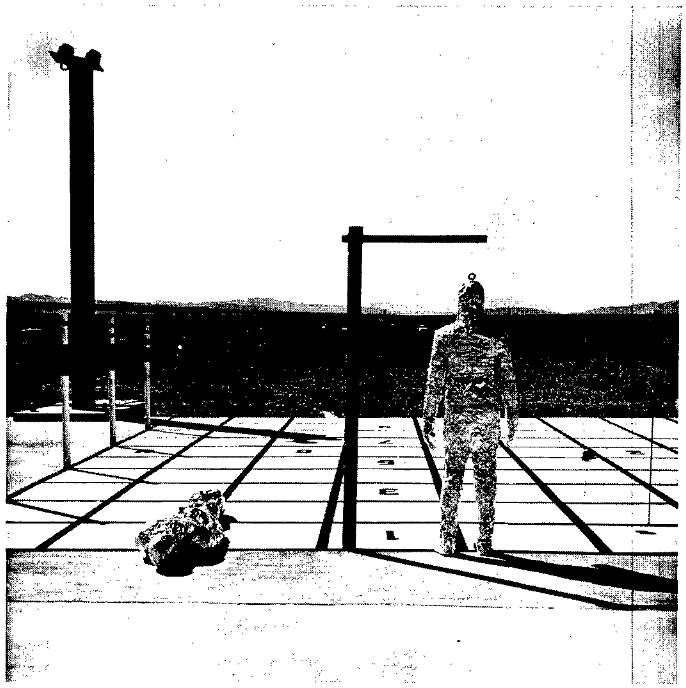


(b)

Fig. 2.8—General arrangement of the dummies and spheres for shot 1. (a) Looking away from GZ. (b) Looking toward GZ.



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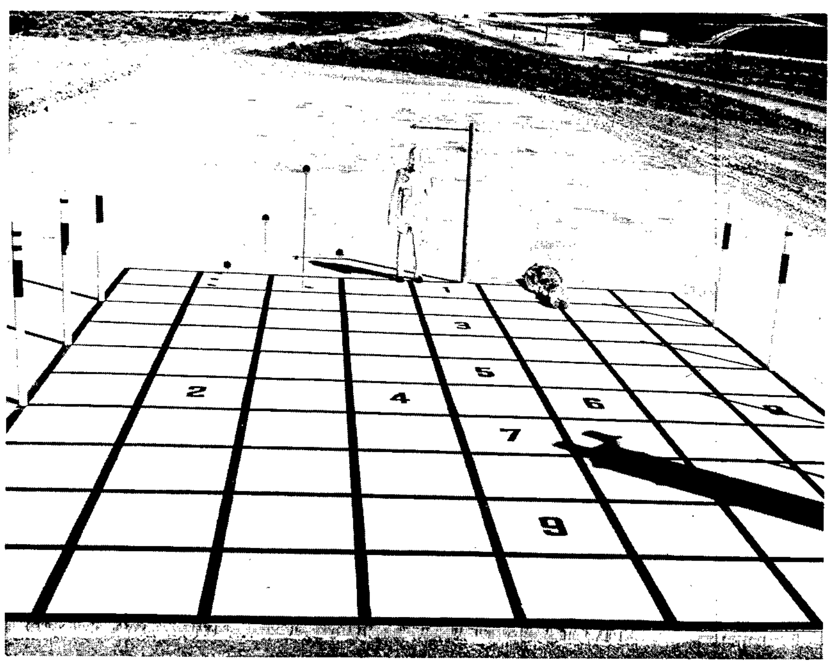

(b)

Fig. 2.9—General arrangement of the dummies and spheres for shot 2. (a) Looking away from GZ. (b) Looking toward GZ.

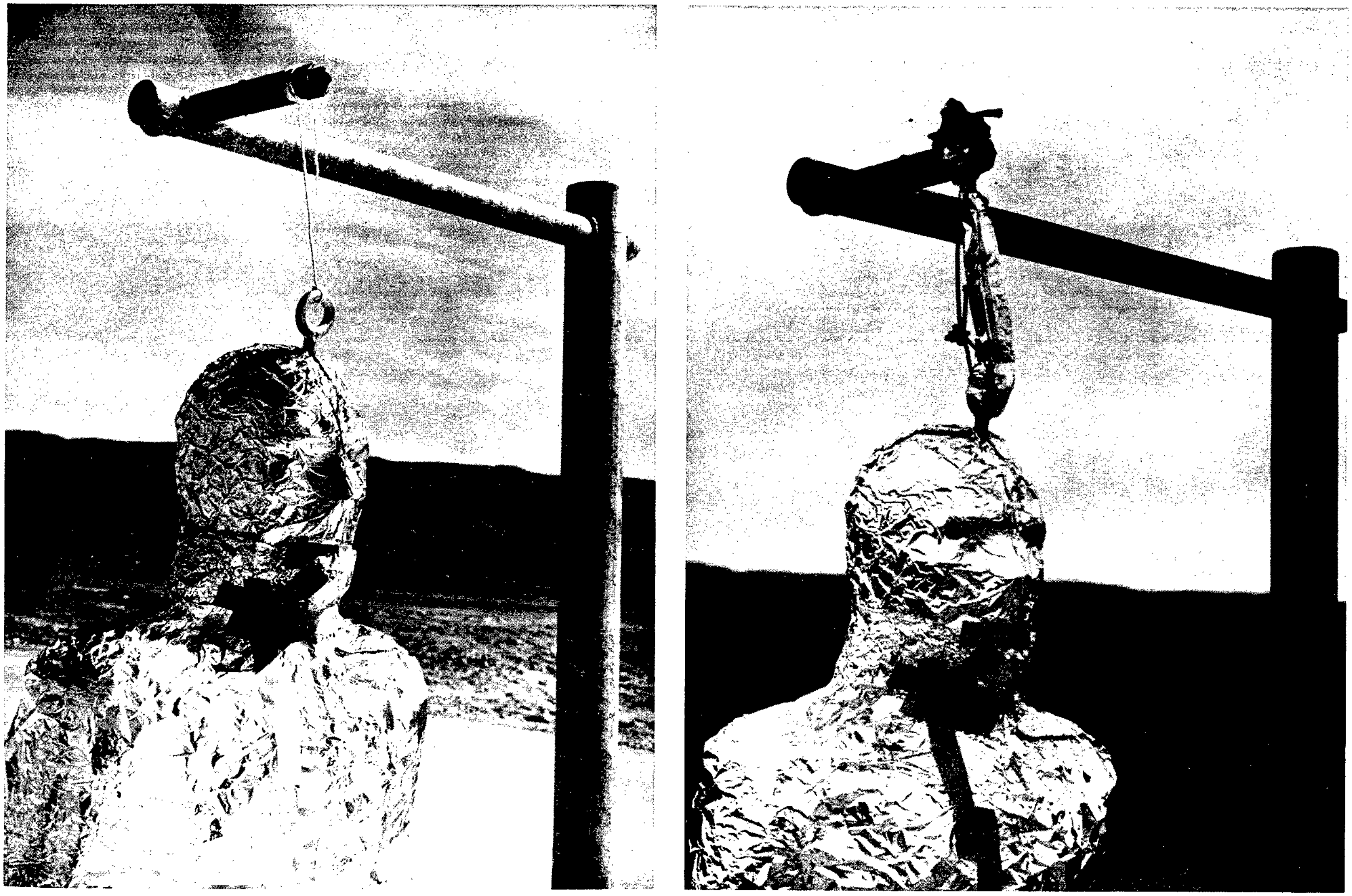

Fig. 2.10—Close-up of dummy as rigged for shot 2.

additional safeguard against the dummy's falling if the light string did break under the load of natural gusts, wire rope of 1/8 in. diameter was rigged. The wire rope offered support when the dummy had ~~moved~~ beyond the maximum elongation at which the light string would ~~break (Fig. 2.10).~~ In each instance the dummy was covered with aluminum foil as protection against thermal radiation (Fig. 2.7).

2.4.2 Equivalent Spheres

Equivalent spheres (see Appendix 2) were used in two ways in the two detonations; (a) spheres, 3.7 in. in diameter and weighing 351 g, were used in connection with the photography of the dummy. The translation of these spheres was recorded on film and analyzed. To explore the lift that an object might experience in the blast, these spheres were placed on supports of various heights but all at the same distance from GZ (Figs. 2.8 and 2.9); (b) several spheres of 7/16 in. diameter and weighing 5.6 g were placed in front of a Styrofoam missile trap. From initial distance, depth of penetration, and calibration of the Styrofoam, an analysis of the movement of the sphere is possible.[2]

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The wire rope would support the dummy if the gusts were to move the dummy sufficiently to break the light string. The wire rope was [illegible] offered little resistance to slipping from the support during the blast wind (Fig. 2.10).

Chapter 3

RESULTS

3.1 ~~MOTION PICTURES~~ SHOT 1 – ANALYSIS

~~3.1.1 Shot 1~~

Rewritten

Three of the four cameras operated successfully, producing three excellent films in which the flight of the dummy throughout the length of the background grid is visible and analytically useful. The flight of a sphere for a distance of about 4 ft is clearly seen also. Data obtained from a preliminary analysis of the films is recorded in Table 3.1.

~~3.1.2~~ Shot 2 3.2 SHOT 2

In this shot the paint of the photography grid burned. The resulting smoke obscured all but a small portion of the field of view. In this small portion, the upright dummy is visible; however, this also is obscured when the blast arrives. The entire field is obscured before any motion of the dummy can be seen. All four films from shot 2 were useless for analyzing the translation of any of the several test objects.

~~3.2~~ DATA 3.3 SUMMARY OF DATA

The data obtained in both detonations are shown in Table 3.1.

Table 3.1—TABLE OF DATA

	Shot 1	Shot 2
Static, psi	~~5.2~~ 5.3	6.6
Dynamic, psi	~~0.25~~ 0.7	15.8
Movement of dummy		
Distance, ft:		
Prone dummy ~~(Figs. 3.1 & 3.2)~~	0 (Fig 3.6)	124 ft and 19.5 ft to the right (Fig 3.7)
Upright dummy ~~(Figs. 3.3 & 3.4)~~	21.9 straight (Fig. 3.8)	255.7 ft and 43.7 ft to the right (Fig 3.9)
3.7-in. sphere, on ground	Not recovered	160 ft and 31.5 ft to the right
3.7-in. sphere, 12 in. high	4.1 in 0.37 ~~4 ft in 0.39~~ sec	Not recovered
3.7-in. sphere, 20 in. high	Not applicable	Not recovered
3.7-in. sphere, 35 in. high	Not applicable	303 ft and 116 ft to the right
3.7-in. sphere, 60 in. high	Not applicable	399 ft and 89 ft to the right
Velocity, ft/sec:		
Prone dummy	0	Not obtained
Upright dummy	~~23~~ 21.9	Not obtained
7/16-in.-diameter sphere	~~A~~ Not Applicable	~~68 to 80~~ 70 to 83 5 spheres, $\bar{v}$ = ~~74~~ ft/sec 75.7
3.7-in. sphere, on ground	18 ~~17~~ at 0.37 ~~0.39~~th sec	Not obtained
3.7-in. sphere, 12 in. high	~~—~~ Not Applicable	Not obtained
3.7-in. sphere, 20 in. high	— "	Not obtained
3.7-in. sphere, 35 in. high	— "	Not obtained
3.7-in. sphere, 60 in. high	— "	Not obtained

Fig. 3.1—Prone dummy after shot 1. The area around the dummy had to be swept to uncover the grid numbers.

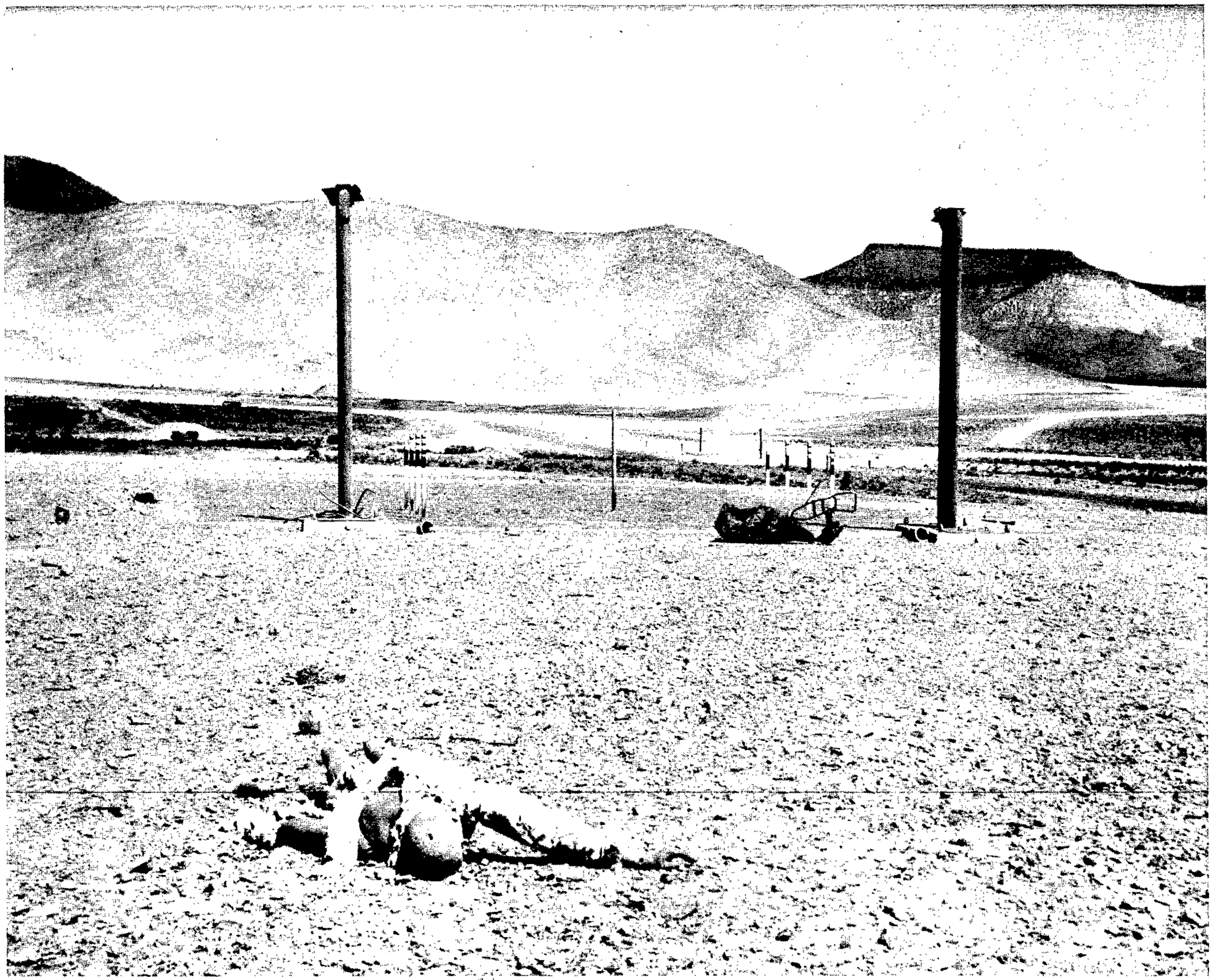

Fig. 3.2—Prone dummy after shot 2.

Fig. 3.3—Upright dummy after shot 1. The area beyond the dummy had to be swept to uncover the grid numbers.

2.9
Fig. 3.4—Upright dummy after shot 2.

Chapter 4

DISCUSSION

4.1 TECHNIQUE OF PHOTO-TRIANGULATION

The requirements that an area be large enough to preclude the entrance of dust into and across the field of view of the cameras and be composed of material which itself will not contribute fine particles to the blast winds may become economically infeasible if the location of interest is within the region of high overpressures and their accompanying high winds. In such circumstances, the application of a technique employing a self-contained emitter and associated receivers might be worth considering. Films of shot 2 will be analyzed to determine the following: whether the blast arrives laden with smoke, with dust, or with both, and, equally important, from what direction does it arrive. Final positions of test objects (Table 3.1) indicate a resultant blast diverging to the right from a straight line from GZ through the center line of the test station.

4.2 VELOCITY DATA

Failure of the photographic technique in shot 2 precludes the development of the path of movement of test objects; however, it is intended to analyze the pressure-time records for this station, the data obtained from the missile traps located at this station, and, with the coordinates of the final positions, attempt to develop some information about the velocity of the test objects.

4.3 EQUIVALENT SPHERES

In shot 1 the area presented by the standing dummy to the wind varied from an initial maximum value to a minimum about 0.5 sec after the shock front arrived, when the dummy was horizontal with the head toward GZ. This behavior exemplifies a changing value of the accelera-

21.4 effective

tion coefficient, a (see Appendix 2). It was the purpose of the equivalent sphere experiment to duplicate the ~~average~~ effective a for the dummy in order that the velocities gained in the same blast situation by the two objects would be the same. ~~Preliminary~~ Analysis showed that the dummy reached a maximum velocity of ~~[illegible]~~ 21.4 ft/sec in about 0.5 sec. The sphere analyzed was obscured by dust after about 0.4 sec, when it was traveling ~~17~~ 16 ft/sec, not having reached maximum velocity. It should be pointed out that the sphere began its displacement from the surface and thus may have been subjected to winds somewhat different from those acting on the dummy at a higher average elevation from the surface.

Although no film records were obtained from shot 2, information was obtained by the measurement of the total displacements of the dummies and spheres and velocities of steel balls caught in traps at the same location. Prone and standing dummies were displaced 124 and 256 ft away from GZ, respectively. Weighted croquet balls placed initially at various heights, from the surface to 60 in. above the surface were displaced from 160 to 399 ft away from GZ. Undoubtedly, the initial position of the spheres influenced the total displacement and probably the maximum velocities obtained. There is, of course, the possibility that the spheres placed at higher elevations traveled farther simply because they had a greater distance to drop before striking the ground. Future analysis making use of measured dynamic pressures should clarify the problems mentioned above. Such an analysis would also make use of the fact that five equivalent spheres caught in nearby traps were traveling from ~~68~~ 70 to ~~80~~ 83 ft/sec after a displacement of 17.1 ft.

omit ?

4.4 Deviations from Theory

new section attached

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Chapter 5

CONCLUSIONS

8.5

The prone dummy moved much less than did the upright dummy in each of the two events, primarily because of the difference in presented area: 1 (prone) to 7 (upright). Another factor, the contribution of which will be determined by analysis, is the position of the presented area, i.e., the object, within the boundary zone of the wind stream. The prone dummy is within the zone of great friction; the upright dummy extends into the zone approaching free flow. An analysis of the behavior of the equivalent spheres which were exactly alike but launched from different heights above ground may disclose the effect of the boundary zone for shot 2 at the location of the dummies.

Appendix 1

DETERMINATION OF DIMENSIONS OF STABILIZED AREA

Determination of the length of an area of stabilization to reduce the dust accompanying a blast wave is possible because of the limited excursion of a particular air molecule, and thus a dust particle. To illustrate: for a device of appropriate yield at the 5-psi maximum overpressure region, it can be computed that during the entire positive phase of about 1 sec an air particle would move about 114 ft. Thus, the length of the stabilized area for shot 1 was made 130 ft to include the 16-ft photography grid.

The distance of travel, or excursion, of an air particle was estimated from the relation of wind speed to time for the 5-psi region, in Shot 1. This relation was computed for a fixed distance from GZ; however, an air particle does not, of course, remain at this fixed distance. Thus, the air particle under consideration begins its journey in a pressure region slightly higher than 5 psi and ends about 114 ft away 1 sec later. During this time the shock front travels about 1200 ft. It is conceivable that a dust particle would overshoot and thus travel farther than the air particle. Since the overshoot would occur near the end of the positive-pressure phase, the effect would be insignificant from the standpoint of photography.

The principle considerations for deciding the width of the stabilized area were (1) entrainment of dust from the adjacent regions and (2) possibility of the shock winds traveling in a nonradial direction from GZ. These phenomena, unfortunately, do not lend themselves to easy numerical evaluation. Thus, the width of the stabilized area for shot 1 was arbitrarily set at 50 ft.

A procedure similar to the one described above was used to compute the length of the stabilized area (195 ft) for shot 2. The width of this area was arbitrarily made 65 ft at the end toward GZ, tapering to 50 ft at the end away from GZ.

or smoke

The material of which the stabilized area is composed must not itself yield dust particles as a result of wind or of thermal radiation. ~~In shot 1 concrete served well; in shot 2 the answer may lie in extensive analysis of the films.~~

Appendix 2

THEORY OF EQUIVALENT SPHERES BASED ON THE ACCELERATION COEFFICIENTS

Mathematical procedures have been used to estimate the velocity acquired by an object free to move when subjected to blast winds.[1,2] The acceleration of a particular object has been shown to be proportional to its presented area and to its drag coefficient, and inversely proportional to its mass. These parameters can be combined into a single quantity designated as the "acceleration coefficient," α, equal to A C_D/m; where A is the presented area in ~~square feet~~, m is mass ~~in pounds~~, and C_D is the drag coefficient. The importance of α lies in the fact that two entirely different objects possessing the same value of α would experience the same acceleration, and thus the same change in velocity, if exposed to the same wind conditions. Thus, it was possible to construct a "model" of a man whose only point of similarity was the equivalence of the acceleration coefficient, α. A convenient shape, one for which the drag coefficient is well known, was the sphere.

In order to make use of the theory of equivalent acceleration coefficients in the construction of models, drag coefficients, while not necessarily equal, should be constant over the range of wind speeds used. The drag coefficient for spheres has been shown[3] to be constant over a range of Reynolds numbers (from about 10^3 to 4×10^5) sufficient for most practical blast situations. Investigations of the drag coefficient for the human body are much less comprehensive. Hoerner[4] reports data obtained from parachutists and ski jumpers. From these data it was surmised that the average value of α for the dummy, initially standing, but later tumbling, is between 0.03 and 0.04 ft^2/pound. The larger equivalent spheres used in this study were made from croquet balls weighted to make the value of α equal to 0.035 ft^2/pound. The smaller spheres used were steel balls of diameters 7/16, 1/2, and 9/16 in., the α values for which are 0.040, 0.035, and 0.031 ft^2/pound, respectively.

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WT-1468 -A -B

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