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Operation

HARDTACK

April - October 1958

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Project 8.3

**GROWTH OF FIREBALL RADII
AT VERY HIGH ALTITUDES (U)**

Issuance Date: May 5, 1961

HEADQUARTERS FIELD COMMAND
DEFENSE ATOMIC SUPPORT AGENCY
SANDIA BASE, ALBUQUERQUE, NEW MEXICO

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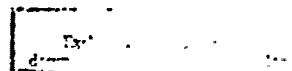
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OPERATION HARDTACK—PROJECT 8.3

GROWTH OF FIREBALL RADI AT
VERY HIGH ALTITUDES (U)

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Boston, Massachusetts

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ABSTRACT

The purpose was to determine, by photographic means, the modes by which energy is propagated and dissipated from nuclear explosions at very high altitudes. A corollary objective was to document all visible aspects of the detonations for later analysis of any unforeseen phenomena.

The project analyzed films from Shots Yucca, Teak, and Orange. Film records analyzed included 70-mm streak records for very early fireball growth, 35-mm high-speed records for diameter-time relationships up to 2,000 msec, and slow-speed 35- and 70-mm records for late diameter-time data. The films were taken from cameras aboard two RB-36 aircraft.

Shot Yucca had an approximate initial diameter of 40 meters at approximately 0.13 msec and could be measured to a diameter of about 640 meters at 1.5 seconds. Shot Orange had an initial observed diameter of approximately 1.7 km and reached a diameter of 20 km at 30.5 seconds.

Shot Teak was a multiphenomena event. At early times, the configuration of the radiation phase was egg shaped. As time passed, several shocklike phases became discernible. The major vertical and major horizontal measurements of each of these phases were computed.

Because of the uncertainties involved in scaling for high-altitude bursts, no attempt was made to calculate yields.

FOREWORD

This report presents the final results of one of the projects participating in the military-effect programs of Operation Hardtack. Overall information about this and the other military-effect projects can be obtained from ITR-1650, the "Summary Report of the Commander, Task Unit 3." This technical summary includes: (1) tables listing each detonation with its yield, time, environment, meteorological conditions, etc.; (2) maps showing shot locations; (3) discussions of results by programs; (4) summaries of objectives, procedures, results, etc., for all projects; and (5) a listing of project reports for the military-effect programs.

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Chapter 1

INTRODUCTION

1.1 OBJECTIVES

The purpose was to determine, by photographic means, the modes by which energy is propagated and dissipated from nuclear explosions at very high altitudes. A corollary objective was to document all visible aspects of the detonations for later analysis of any unforeseen phenomena.

1.2 BACKGROUND AND THEORY

High-speed photography of low-altitude detonations, during many operations, has shown that the initial propagation of energy from a nuclear explosion is by radiative transport (radiative phase), which is overtaken in a matter of tens of microseconds by hydrodynamic (fireball) transport. Results from Shot 15 during Operation Teapot (Shot 15) at 56,600 feet show that the radiative phase persisted for a considerably longer time than was the case for a similar low-altitude burst (Reference 1). The partition of energy between shock and radiation changes slightly at approximately 24,630 feet; however, a tremendous change was to be expected at extreme altitudes. These phenomena and theoretical considerations are discussed in Reference 2, issued in 1954, prior to Operation Teapot.

The attenuation of radiation of very short wavelength (less than 2,500 angstroms) is complete within a few centimeters at sea level; however, at 250,000 feet these thermal radiations were expected to penetrate several hundred meters. It was postulated that the entire energy release might be radiated without forming any fireball.

Chapter 2

PROCEDURE

2.1 SHOT PARTICIPATION

This project participated in shots Yucca, Teak, and Orange.

All times given in this section have been corrected for WWVH transit time.

Yucca, a nominal 1.7-kt device, was detonated on 28 April 1958 at local time 1440:00.256 ± 2 msec (Greenwich Mean Time 0240:00.256 ± 2 msec, 28 April 1958). The device was suspended from a balloon at an altitude of 84,683 feet above sea level ($\rho_0 = 3.5 \times 10^{-5}$ gm/cm³) (Reference 3), and was detonated at a location between Eniwetok and Bikini Atolls in the Eniwetok Proving Ground.

Teak, a nominal 3.8-Mt device, was detonated on 31 July 1958 at local time 2350:05.596 ± 1 msec (GMT 1050:05.596 ± 1 msec, 1 August 1958). The device was carried northwest of the launching pad, to a firing altitude of 250,374 feet ($\rho_0 = 3.4 \times 10^{-5}$ gm/cm³) (References 3 and 4) by a Redstone missile launched from Johnston Island.

Orange, also a nominal 3.8-Mt device, was detonated in the same manner as Teak on 11 August 1958 at local time 2330:08.605 ± 1 msec (GMT 1030:08.605 ± 1 msec, 12 August 1958). The burst occurred southwest of the Johnston Island launching pad at an altitude of 141,000 feet ($\rho_0 = 3.2 \times 10^{-5}$ gm/cm³) (References 3 and 4).

2.2 PHOTOGRAPHIC COVERAGE

Photographic coverage for all events was supplied by cameras mounted in two RB-36 aircraft flying at altitudes of approximately 37,000 feet for Yucca, and 30,500 feet for Teak and Orange. Positioning data for the participating aircraft is given in Table 2.1. Additional cameras were located on the USS Boxer for Yucca and on Johnston Island for Teak and Orange.

The primary high-speed photography was accomplished by means of streak cameras, which utilized 70-mm film to provide a wide field of view. The purpose of this type camera was to produce a film on which was recorded the envelope of the expanding phenomena. To accommodate possible errors in aiming and/or burst position, the cameras were operated without a slit. At a nominal film speed of 20 ft/sec, the cameras, operating with a slit, would be capable of resolving a few microseconds; and without a slit, better than a hundred microseconds. With a 6-inch lens, the spatial resolution is a few meters.

Three streak cameras were used in each aircraft—two mounted to record the vertical growth of the fireball, and one mounted to record its horizontal growth. Because the exposure was relatively unpredictable, the cameras were filtered to respond to different light levels.

One streak camera on the USS Boxer for Yucca and one on Johnston Island for Teak and Orange were equipped with longer lenses so that a record of the envelope of horizontal growth could be obtained in the absence of cloud cover.

Other cameras used included the following: 35-mm Fastax (2,000 frames/sec)—fireball photography; 35-mm Mitchell (24 frames/sec)—fireball photography; 70-mm Hulcher (Edgerton, Germeshausen & Grier modified) cloud $1/4$ frame/sec—later stages of cloud formation; 70-mm Maurer ($3\frac{1}{2}$ frames/sec)—later stages of cloud formation; and 16-mm gun sight aiming point (64 frames/sec)—distribution of light over the sky (employed ultra-wide-angle lenses) and documentary (both color and black and white).

Timing signals at each station activated the cameras and control equipment. Upon receipt of the time signal, operation of each station was automatic.

2.3 FILM READING AND DATA REDUCTION

The 35-mm films were measured on a Hauser profile-measuring microscope equipped with an Edgerton, Germeshausen & Grier (EG&G) fireball image reading device. The 70-mm streak records on Yucca and Orange were read on a Mann optical comparator, and the Teak streak records were read using a Bausch and Lomb magnifier and a finely scribed 100-micron scale.

The data was processed on the Burroughs E-102 digital computer.

Zero time for the Yucca and Orange streak records was established as the center of the circle that made the best fit to the head of each trace. On Teak, the envelope was less opaque, and streak zero times were measured at the tip of the well-defined inner envelope (Figure 4.25).

Zero times for the 35- and 70-mm framing records were determined by comparison with early diameter measurements taken from the streak records.

Sample camera data and calculation sheets are contained in Appendix A.

2.4 DETERMINATION OF MAGNIFICATION FACTOR

The airborne cameras were mounted perpendicular to the longitudinal axis of the aircraft and elevated to the angles indicated in the photo plan sheets for the various shots (see appendixes).

To determine a magnification factor for relating film dimensions to object size, the distance was calculated along the optical axis of each camera to the point in space where the axis intercepted, at right angles, the plane containing the burst. By measurement on the film of the horizontal and vertical displacements of the image from the center of the frame, the angles between the optical axis of the camera lens and the slant range to burst were obtained. Because the rate of rise of each of the detonations was unknown at the time of analysis and was beyond the scope of the analysis effort, no attempt was made to correct the measurements for viewing geometry. It is hoped that future analysis will yield enough information to enable a correction of diameter values.

The true range ($R_{t/a}$) along the optical axis, to be used in determining the magnification factor, was then calculated as follows:

$$R_{t/a} = d_1 \cos \alpha \cos \beta + (h_b - h_c) \sin \beta$$

Where: d_1 = horizontal distance—camera to burst

β = camera elevation from horizontal

α = angle between $R_{t/a}$ and slant range in horizontal or ground projection

h_b = height of burst

h_c = height of camera

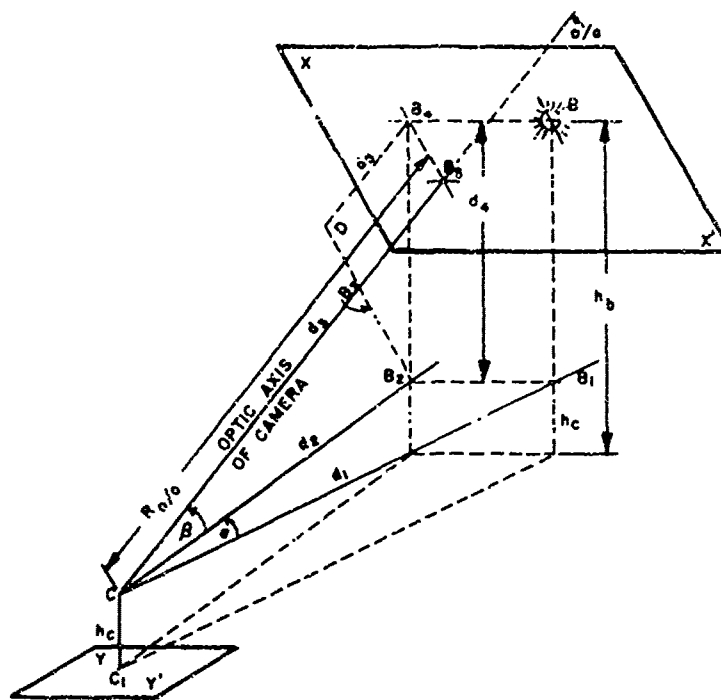
Figure 2.1 is a spatial presentation of the range along the optical axis.

TABLE 2.1 POSITIONING DATA

Location	Coordinates		Altitude ft	Distance, Aircraft to Burst	
	N	E		Horizontal	Slant Range
Shot Yucca					
Air zero	451946*	364042*	84,683	—	—
RB-36, 15748 (Station 830.01)	426552*	337621*	36,000	79530	85692
RB-36, 15750 (Station 830.02)	498747*	292340*	37,000	65058	80666
Shot Teak					
Air zero	203144†	184871†	156,371	—	—
Launch pad	0040†	200580†	~0	—	—
Center Johnston Island	19130†	197855†	~0	—	—
RB-36, 15748 (Station 830.01)	51269†	16432†	30,500	390196	447507
RB-36, 15750 (Station 830.02)	59†	377278†	30,500	383859	450220
Shot Granite					
Air zero	63198†	196052†	141,609	—	—
Launch pad	200040†	200580†	~0	—	—
Center Johnston Island	199130†	197855†	~0	—	—
RB-36, 15748 (Station 830.01)	461248†	21056†	30,500	434794	448422
RB-36, 15750 (Station 830.02)	461608†	381646†	30,500	439432	453091

* Referenced to Eniwetok coordinate system.

† Referenced to Johnston Island coordinate system.



KEY TO SYMBOLS IN FIGURE:

B: BURST POINT IN SPACE.
 C: CAMERA LOCATION.
 o/a: OPTICAL AXIS OF CAMERA.
 XX': PLANE THROUGH B PERPENDICULAR TO o/a. THIS IS THE PLANE IN WHICH THE CAMERA SEES THE BURST.
 YY': HORIZONTAL DATUM PLANE.
 C1: PROJECTION OF C ON YY'.
 CC1: HEIGHT OF CAMERA = h_c .
 B1: PROJECTION OF B ON HORIZONTAL PLANE THROUGH THE CAMERA.
 $h_b - h_c$: HEIGHT OF BURST MINUS HEIGHT OF CAMERA.
 d_2 : PROJECTION OF o/a ON A HORIZONTAL PLANE THROUGH THE CAMERA.
 B_2 : PROJECTION OF B ON CB_2 .
 B_3 : PROJECTION OF B ON o/a.
 B_4 : PROJECTION OF B ON VERTICAL PLANE THROUGH C.
 B_5 : PROJECTION OF B ON o/a.
 D: A CONSTRUCTION POINT.
 α : HORIZONTAL OFF-AXIS ANGLE OF THE OPTIC AXIS.
 β : THE ANGLE OF ELEVATION OR POSITION ANGLE OF THE o/a.
 h_b : HEIGHT OF BURST.

DERIVATION OF $R_{0/a}$:

ADDITIONAL SYMBOLS:

$R_{0/a}$: RANGE OF BURST ALONG o/a

d_1 : HORIZONTAL RANGE TO BURST

DERIVATION:

$$d_2 = d_1 \cos \beta$$

$$d_3 = d_2 \cos \alpha = d_1 \cos \beta \cos \alpha$$

$$d_4 = h_b - h_c$$

ANGLE $DB_2B_3 = \beta$ BY CONSTRUCTION

$$d_3 = d_1 \sin \beta \sin \alpha + (h_b - h_c) \sin \beta$$

$$R_{0/a} = d_3 + d_4$$

$$= d_1 \cos \beta \cos \alpha + (h_b - h_c) \sin \beta$$

Figure 2.1 Derivation of range along the optical axis ($R_{0/a}$) for off-axis bursts.

Chapter 3

SHOT YUCCA: CAMERA INSTRUMENTATION, ANALYSIS, AND RESULTS

3.1 INSTRUMENTATION AND CAMERA OPERATION

Photographic coverage of fireball growth was provided by cameras mounted in two RB-36 aircraft (Stations 830.01 and 830.02) and by cameras mounted on the USS Boxer (Station 943).

Streak Camera 6 (in aircraft Station 830.01) jammed, but all other airborne cameras obtained records of the detonation. Rain clouds partially obscured the burst from the cameras located on the USS Boxer, and the streak camera at the station jammed; thus, no records suitable for analysis were obtained from Station 943. Analysis for Yucca was accomplished by measurement of records from the airborne camera stations.

The Yucca photo plans and photo loading charts are contained in Appendix B. The aircraft positions and survey data are presented in Figures 3.1 and 3.2.

3.2 RESULTS

The Yucca diameter-time plot is shown in Figure 3.3. Because of apparent differences between the curves of the Yucca streak records, they are plotted separately and labeled with the station number and the density value of the camera filter. Neutral density (ND) filters were used on the streak cameras to attenuate the light. The ND filter is a non-discriminating filter in that it attenuates the light by a fixed percentage over the visible spectrum. ND filters are numbered in accordance with the percentage of light they transmit, e.g., an ND-1 transmits 10 percent of the incident light, while an ND-2 transmits only 1 percent of the incident light. Two facts are readily apparent when these curves are compared: (1) at any comparable time, the diameter values of the records from any one station show a filter dependence, i.e., the greater the filter density, the smaller the diameter; and (2) there is poor agreement among curves plotted from records obtained from cameras equipped with filters of the same density value, e.g., the streak curve from the Station 830.01 camera that used an ND-4 filter is higher at any given time than the curve from the corresponding camera record at Station 830.02.

The differences in image density, attributable to the filtering, is demonstrated when the photographic prints of the three streak records from Station 830.01 are compared (Figures 3.10, 3.11, and 3.12). The camera with the least filtering, ND-3, produced the brightest image, and the camera with an ND-5 filter produced the faintest image.

The use of filters of different values was necessary because very little information was available on high-altitude detonations, making precalculations of expected light intensity unreliable. The filter values were chosen to provide an exposure variation that would insure adequate coverage over a wide range of light intensity.

To determine the nature of the light distribution across the fireball, microphotometric measurements were made on the streak records (by scanning across each streak, orthogonal to the time axis). Examination of these results showed that the light intensity across

the fireball was nonuniform, rising to a maximum at the fireball center. Figure 3.4 shows a curve of relative light intensity distribution across the face of the fireball. Superimposed on the curve are rectangles representing the filters used and showing the relative range of light intensity encompassed by each. The ND-3 filter passes the widest range of light intensities, while the ND-5 passes the narrowest range. The image width and consequently the calculated diameter is, in this case, dependent upon the intensity range of the filter.

To determine the cause of disagreement among the curves of records made from cameras using similar filters, microphotometric measurements were made on each record at 0.8 msec and at 15 msec. Comparison of microphotometric traces of two records with the same degree of filtering and exposed at the same time showed that the width of the streaks was the same, but the density of the images was markedly different. The trace with the lighter image, when magnified on the optical comparator, was much more difficult to measure because of poor definition at the extremities. In all cases the measurement of the denser image resulted in a higher calculated diameter. The difference in image density is attributed not only to the difficulty in defining the edge of a gradually changing density, but also to variations in the photographic process. The conditions for processing 70-mm records in the field were such that photosensitometric control was difficult to attain.

An ND-2 filter was used on the Fastax camera mounted in Station 830.02, and the diameter values calculated from measurements of its record are greater at any given time than the values calculated from measurement of the least heavily filtered streak record from either station. This fact supports the observation that the light distribution across the face of the fireball is nonuniform and that the filter density value affects the apparent size of the streak records.

At approximately 20 msec, an inner core becomes discernible on the film records, as the core grows, assuming the characteristic torus- or doughnut-shaped cloud approximately 4.5 seconds after zero time.

Figures 3.5 through 3.12 show the fireball, the cloud development, and the streak records.

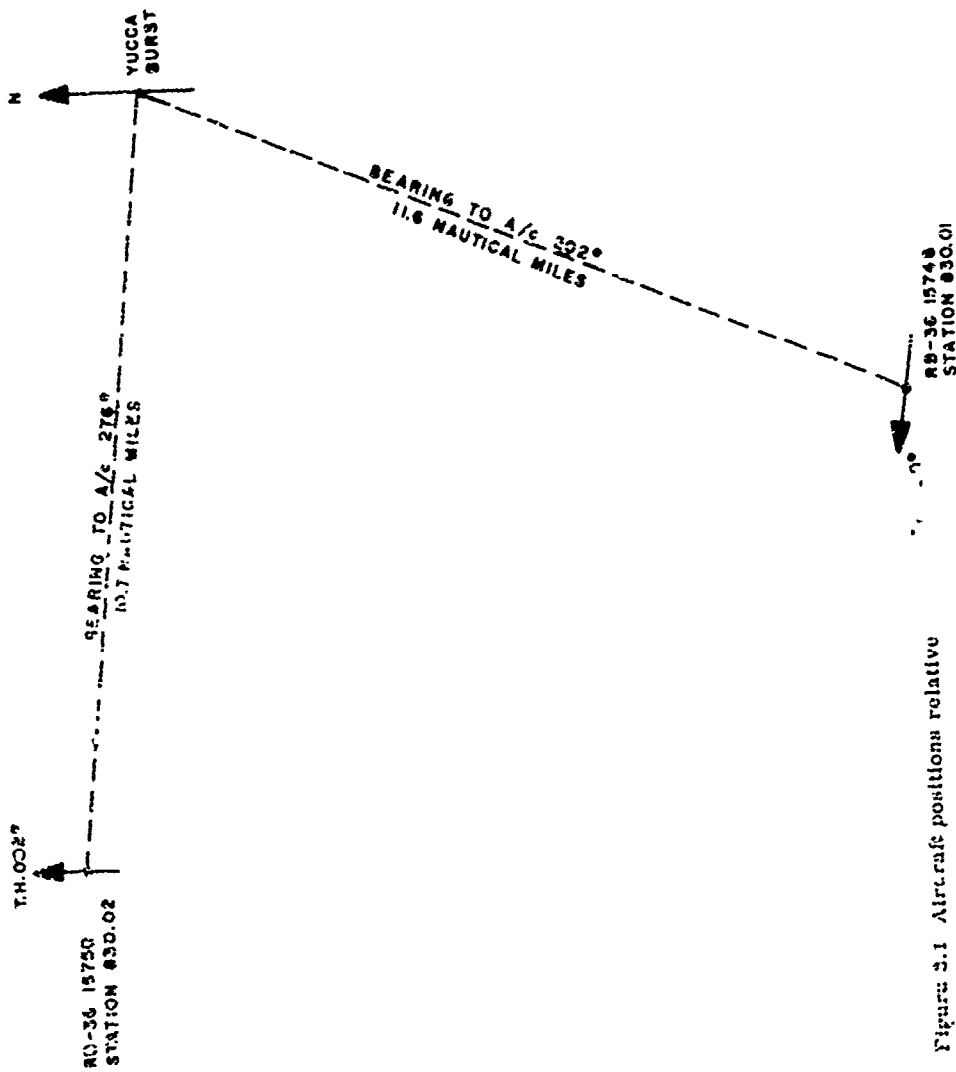


Figure 3.1 Aircraft positions relative to Yucca Burst, Shot Yucca.

DATE: 5-12-59

SURVEY DATA

SZ STA. HEAD SURVEY

MUSEA

STA.	COORDINATES			FROM PHOTO STA.			DIST. HOR.		TANGENTS		ANGLES	
	N	E	Z	ΔN	ΔE	ΔZ	FT.	M.	ΔE/ΔN	ΔZ/DIST.	BRG	TILT
G.S.	491946	364042	85480									
B204												
49-24	491552	337621	36000	65321	26921	40680	70730	81498	6.4043	0.48120	211°00'	34.57°
49-25A												
B30-02	490297	288390	37000	62001	44702	47680	65057	75830	7.17360	0.73280	96°00'	36.0°
49-25B												
EMINGTON COORDINATE SYSTEM												
BEARING ANGLES REFERRED TO TRUE ANGLE FROM PHOTO STA. IN ENCL. SHEET 11550												
TILT ANGLES ARE MEASURED FROM PHOTO STA. 12 THRU SEA OR AIR LEVELS.												

Figure 3.2 Survey data, Shot Y, c.

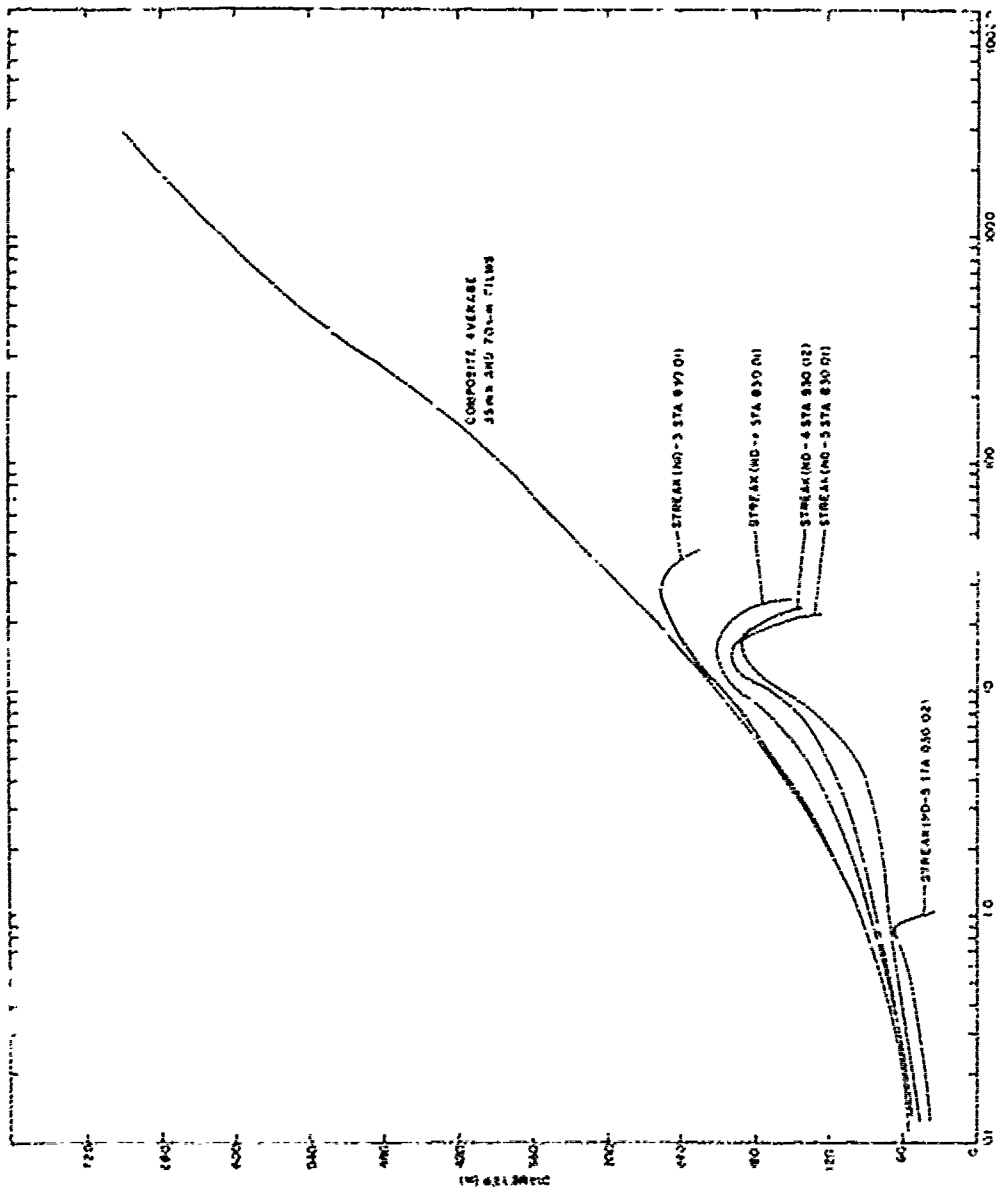


Figure 3.3 Diometer-time plot, Shot 1 uccl.

Figure 4.3 Diometer-time plot, Shot 1 uccl.

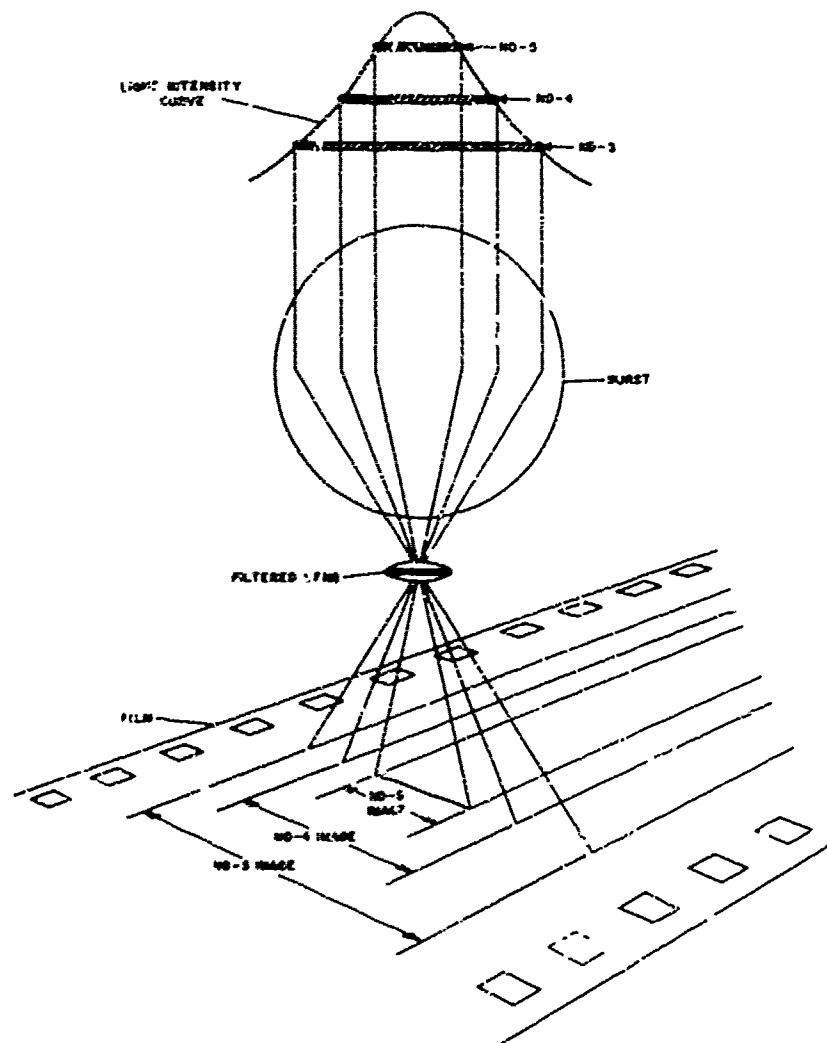


Figure 3.4 Relationship between filter rating and image width of strzak records.

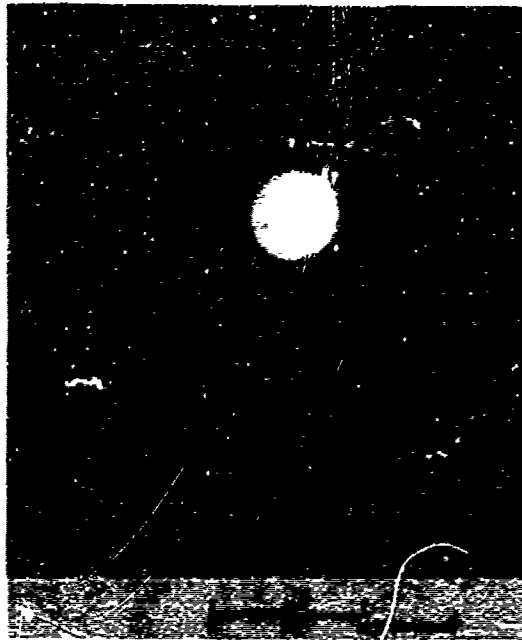


Figure 3.5 Fireball at approximately 0.6 msec, Station 830.02, 35-mm Fastax FF camera, Shot Yucca.



Figure 3.6 Cloud development at approximately 3.0 seconds, Station 830.02, 70-mm Cloud Camera 4, Shot Yucca.



Figure 3.7 Cloud development at approximately 7.5 seconds, Station 830.02, 70-mm Cloud Camera 4, Shot Yucca.

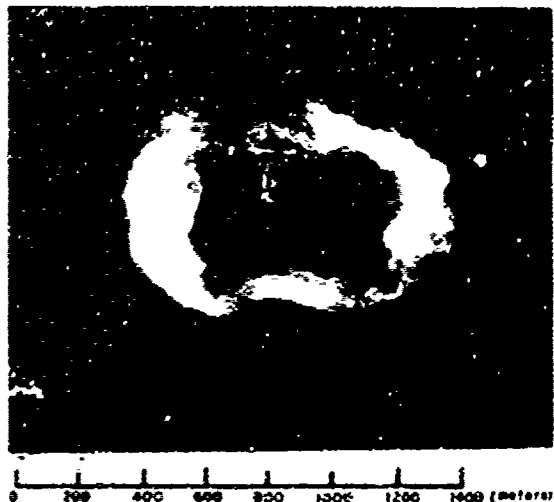


Figure 3.8 Cloud development at approximately 8.5 seconds,
Station 830.02, 70-mm Cloud Camera 4, Shot Yucca.



Figure 3.9 Cloud development at approximately 12.3 seconds,
Station 830.02, 70-mm Cloud Camera 4, Shot Yucca.

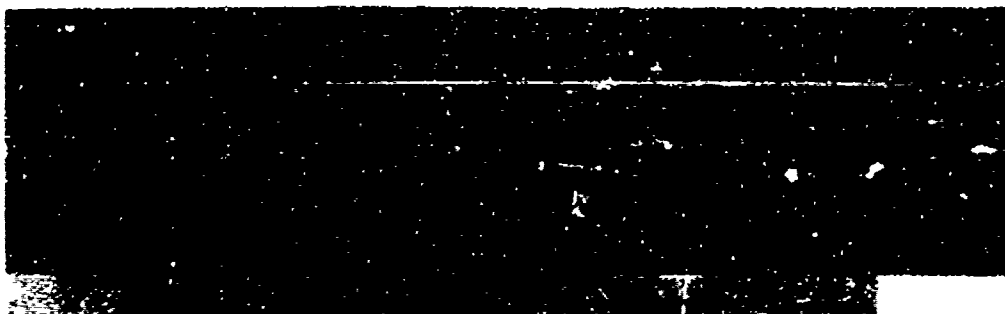


Figure 3.10 Streak record, Camera 3, ND-3 filter (horizontally mounted),
Station 830.01, Shot Yucca.



Figure 3.11 Streak record, Camera 2, ND-4 filter (horizontally mounted),
Station 830.51, Shot Yucca.



Figure 3.12 Streak record, Camera 1, ND-5 filter (vertically mounted),
Station 830.01, Shot Yucca.

Chapter 4

SHOT TEAK: CAMERA INSTRUMENTATION, ANALYSIS, AND RESULTS

4.1 INSTRUMENTATION AND CAMERA OPERATION

Photographic coverage of the Teak detonation was provided by cameras mounted in two RB-36 aircraft (Stations 830.01 and 830.02) and by cameras mounted in a C-6 truck on Johnston Island (Station 851) (Johnston Island coordinate system). The photo plans and photo loading charts are contained in Appendix C. The aircraft positions and survey data are presented in Figures 4.1 and 4.2. All cameras operated normally except the 35-mm Fastax at Station 830.02.

The streak camera records from Shot Yucca showed that the ND filter values used on the cameras (ND-5, ND-3, and ND-2) were too high for the light intensity levels of the detonation, consequently, the filter values were reduced (ND-4, ND-3, and ND-1) for the three streak cameras at each station recording the Teak and Orange events. Streak cameras were mounted, as for Yucca, to record both the vertical and horizontal diameter.

Because the device-carrying missile did not follow the planned course, the detonation took place outside the field of view of all Johnston Island cameras, except station 851 cameras with very wide fields of view, thus, no data suitable for early-time analysis was obtained from the Johnston Island cameras. Fortunately, the burst did take place within the fields of view of all of the cameras in both aircraft.

4.2 RESULTS

The phenomena recorded during the Teak shot were much different from those observed on any other detonation. For the purposes of this report, these unique dimensional phenomena have been assigned designators D_0 , D_1 , D_2 , and so forth.

At early times, the fireball was approximately egg-shaped, being symmetrical about the vertical axis and asymmetrical in the vertical direction. At 1 msec, the maximum vertical measurement of the radiative phase D_1 (Figure 4.3) was approximately 17 km, and the maximum horizontal measurement was approximately 13 km. The vertical asymmetry is believed to have been caused by the variation in air density across the fireball. At an altitude of 250,000 feet, the lower air density at the top of the burst provides a longer mean-free path for early radiation, resulting in an egg-shaped configuration. Because of the asymmetry of the fireball, measurements were taken along both the major horizontal and major vertical diameters. The diameter-time plots are shown in Figures 4.3 and 4.4. Linear plots of both horizontal diameter and vertical diameter versus late times are shown in Figures 4.5 and 4.6. As in the case of the Yucca diameter versus time plots, wherever there is important disagreement among streak diameter data, the curves have been plotted separately and labeled according to station and filter number.

D_0 is a shocklike phenomenon visible at early times (Figure 4.9). At approximately 900 msec, the light intensity of this phase has fallen off to such a degree that further

measurements on the film record are impossible. The phenomenon designated D_1 appears to be a strong radiation phase brighter than D_0 , but much less intense than D_2 (Figure 4.9). D_2 is a high light-intensity phase whose light level drops below the threshold necessary for good film resolution approximately 1 second after zero time.

Another shocklike front moves up the radiative phase of the burst (Figure 4.12). This front was not measured, because there does not appear to be any satisfactory measurement reference point.

The designator D_3 refers to that phase of the detonation that appears in the streak records as a wedge (Figure 4.25) and in the framing camera records as a bright shock (Figure 4.12). The D_3 phase grows rapidly, and approximately 900 msec after zero time, a bright core (D_3) is discernible in the records (Figure 4.12). This core has the apparent elliptical shape that the viewing geometry would be expected to induce on the bomb-debris torus.

About 3 seconds after zero, a shocklike front (D_4) grows from the core (Figure 4.13). This phase can be measured, in the vertical direction only, to approximately 8 seconds, after which time the light intensity drops sufficiently to preclude further measurement.

The linear plot of horizontal diameter versus late time (Figure 4.5) shows an apparent disagreement between D_3 values from Mitchell (35-mm) and Maurer (70-mm) films. The differences are probably due to the degree of personal judgment required in reading the larger and less well-defined images of the 70-mm Maurer records.

Approximately 7 seconds after zero, a luminescent phenomena rises from the bottom of the radiation envelope (Figures 4.15 and 4.16).

A strong aurora first becomes apparent in the photographs approximately 50 m after zero (Figure 4.16).

Photographic prints showing phenomena growth are shown in Figures 4.7 through 4.22. Several prints (Figures 4.7 and 4.9) show bright spots below the burst; these are internal camera reflections and are not functions of the burst.

Streak records are shown in Figures 4.23 through 4.26. Density variations across the streak image are apparent on some prints (Figures 4.25 and 4.26). These variations are attributed to the photographic processing techniques employed. Because of inadequate field facilities, processing under strict photo densitometric control was not possible.

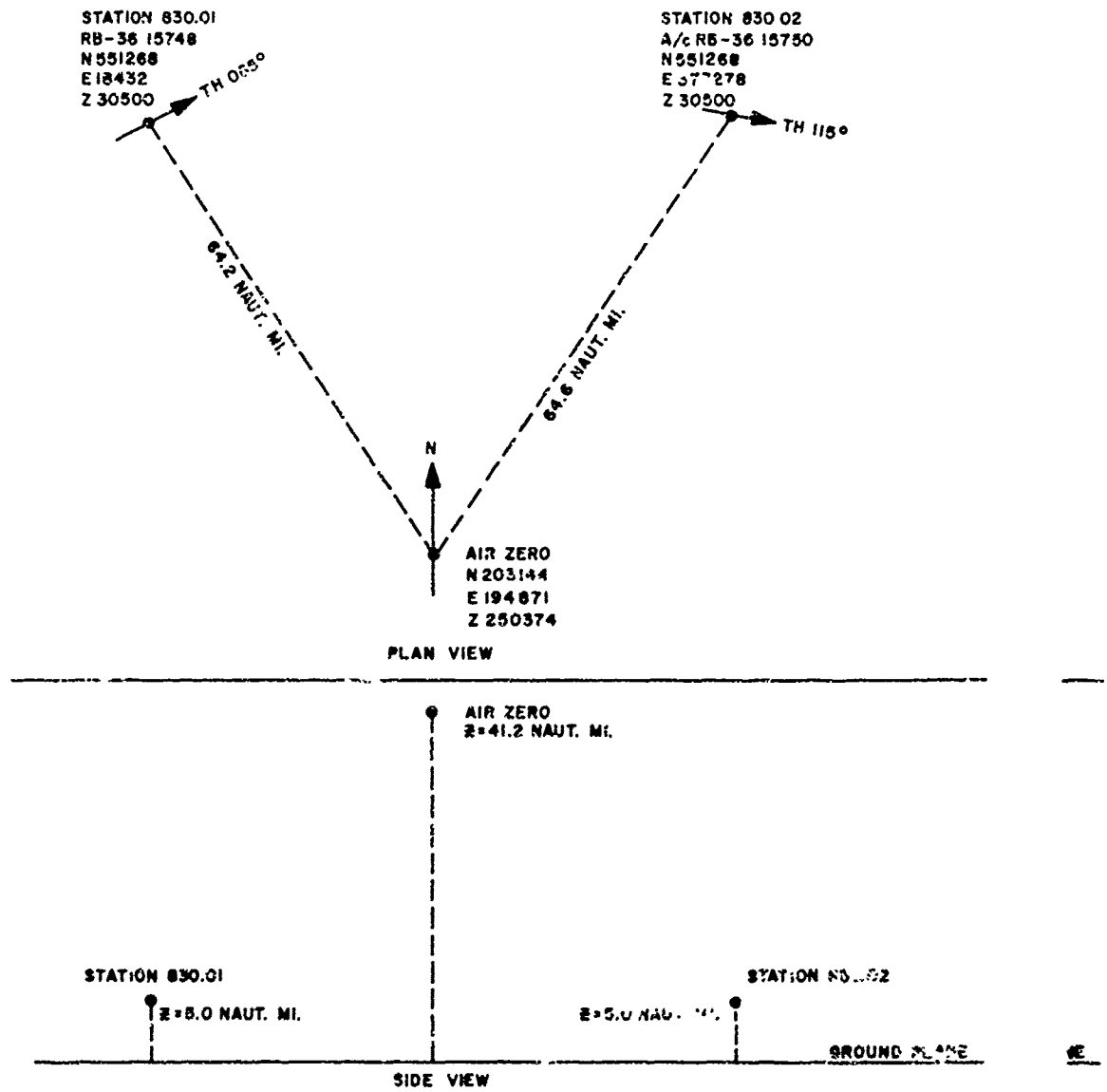


Figure 4. Aircraft positions relative to burst, Shot Teak.

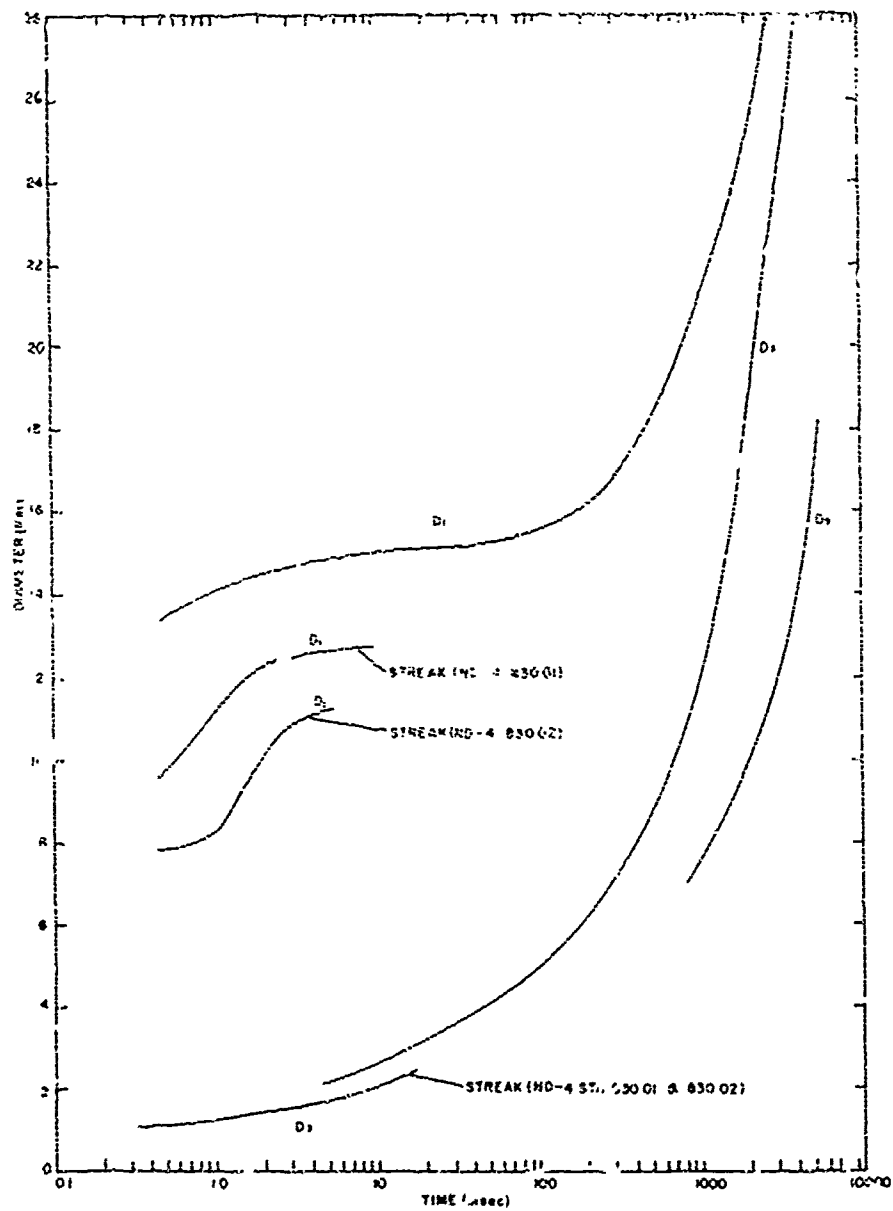


Figure 4.3 Horizontal diameter-time plot, Shot Teak.

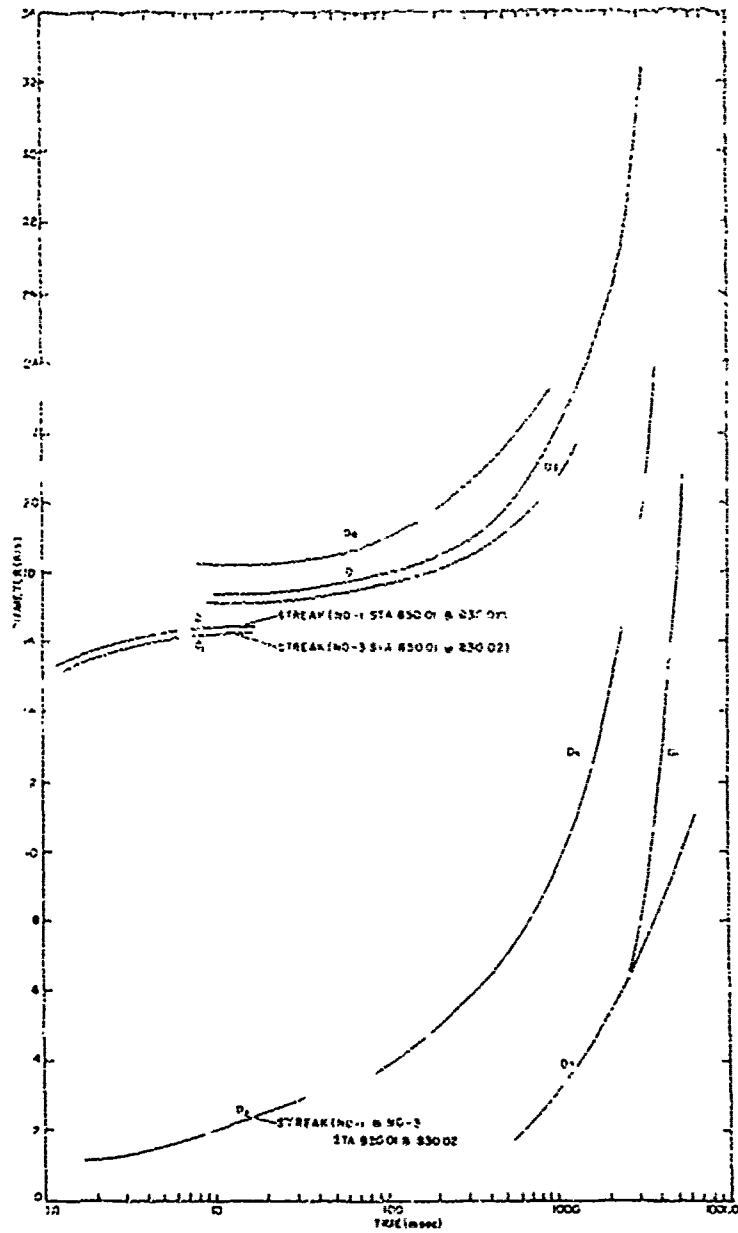


Figure 4.4 Vertical diameter-time plot, Shot Teak.

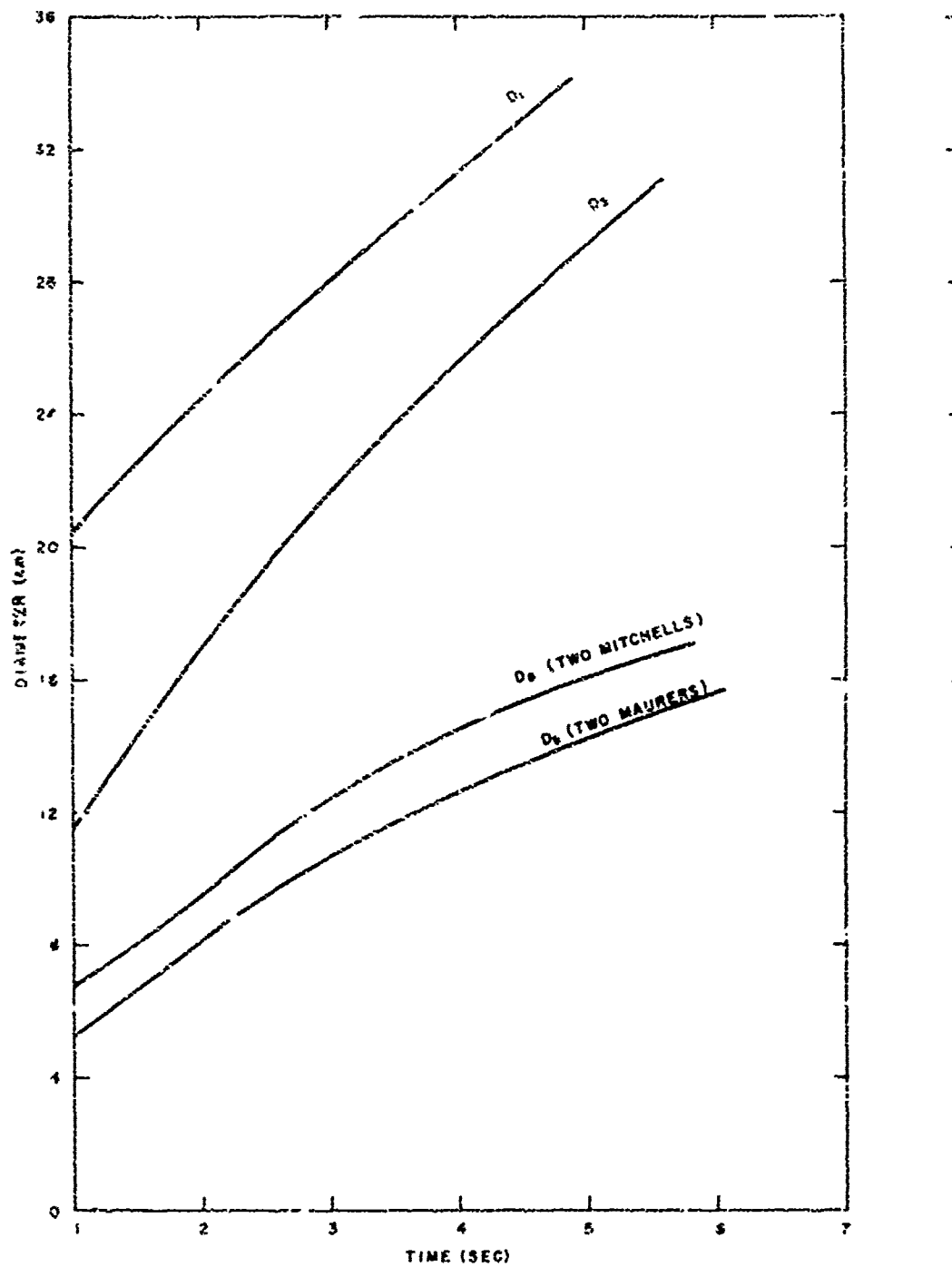


Figure 4.5 Horizontal diameter versus late time, Shot Teak.

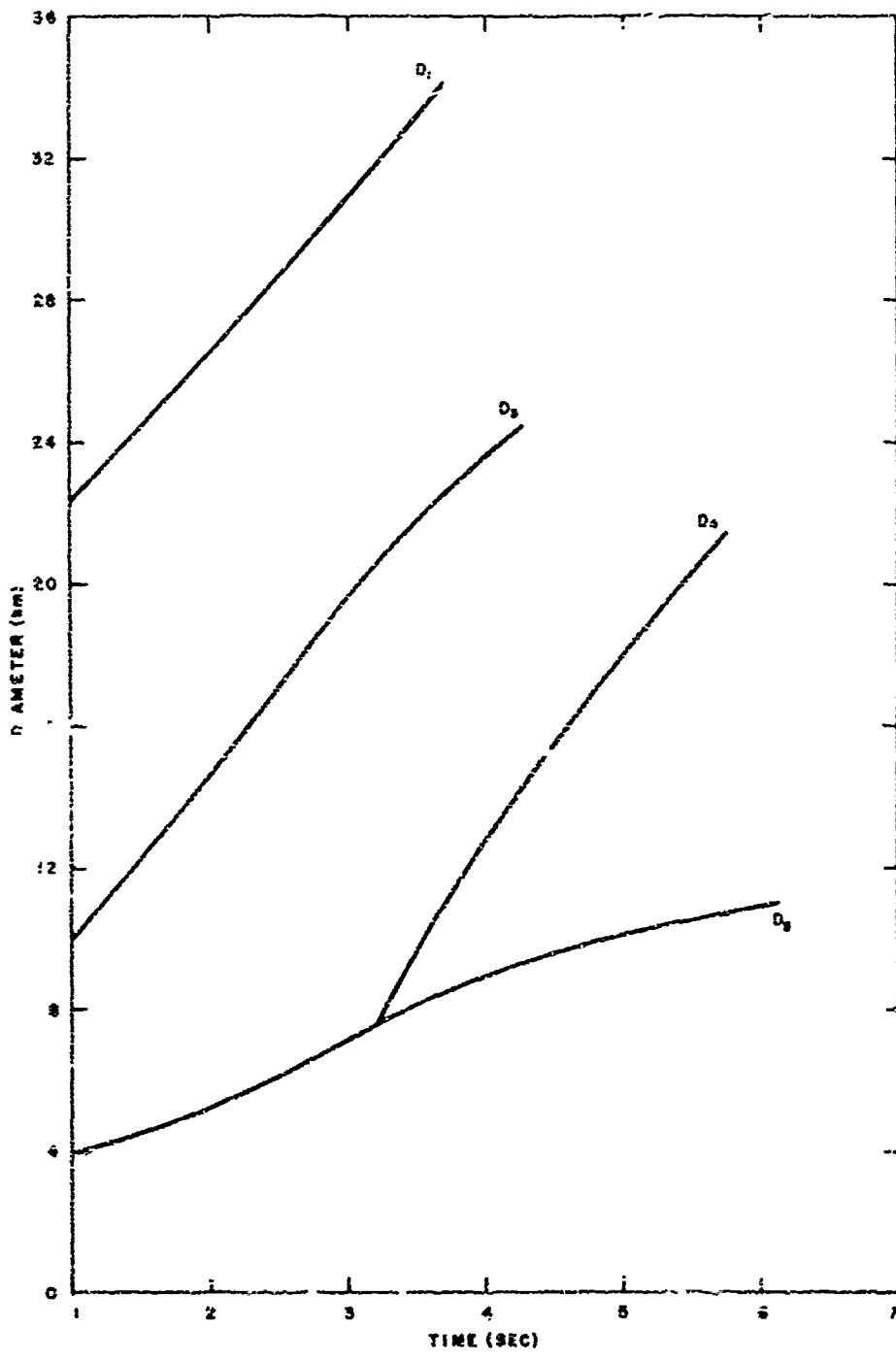


Figure 4.6 Vertical diameter versus late time, Shot Teak.

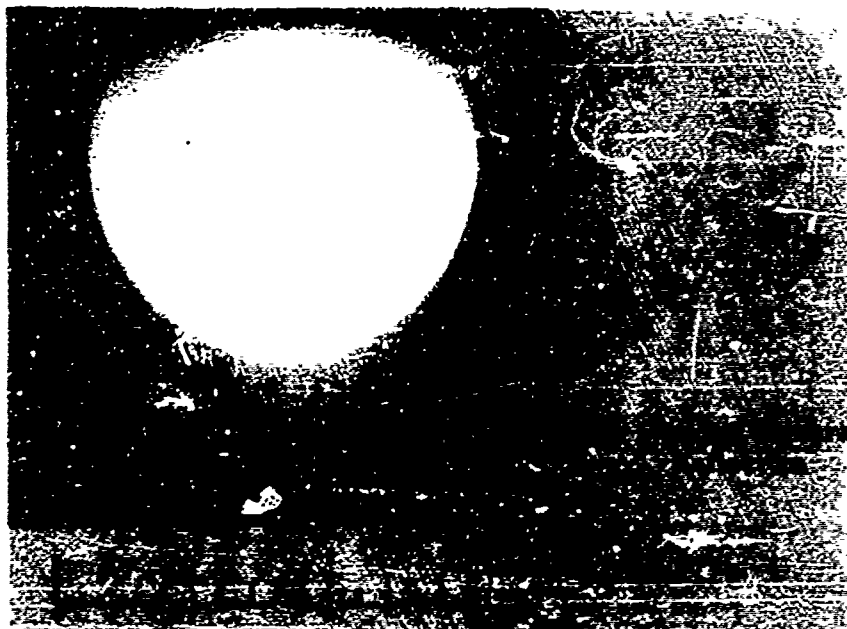


Figure 4.7 Fireball at 0.58 msec, Station R30.01,
35-mm Fastax FF-1 camera, Shot Test.

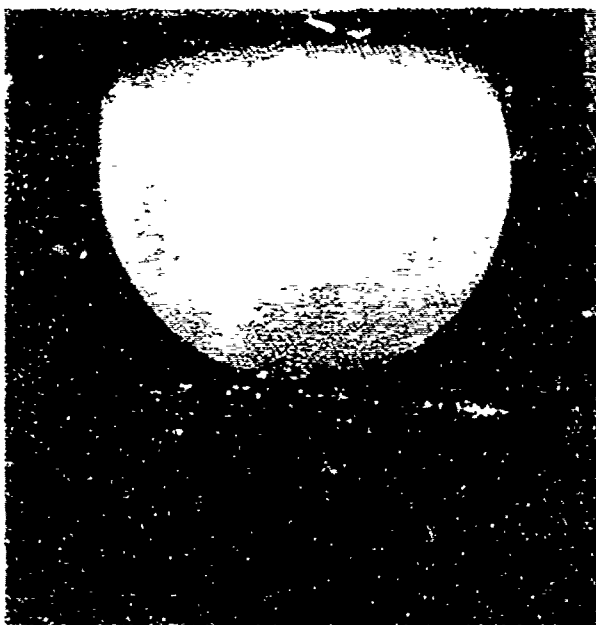


Figure 4.8 Fireball at 9.96 msec, Station R30.01,
35-mm Fastax FF-1 camera, Shot Test.

56

SECRET

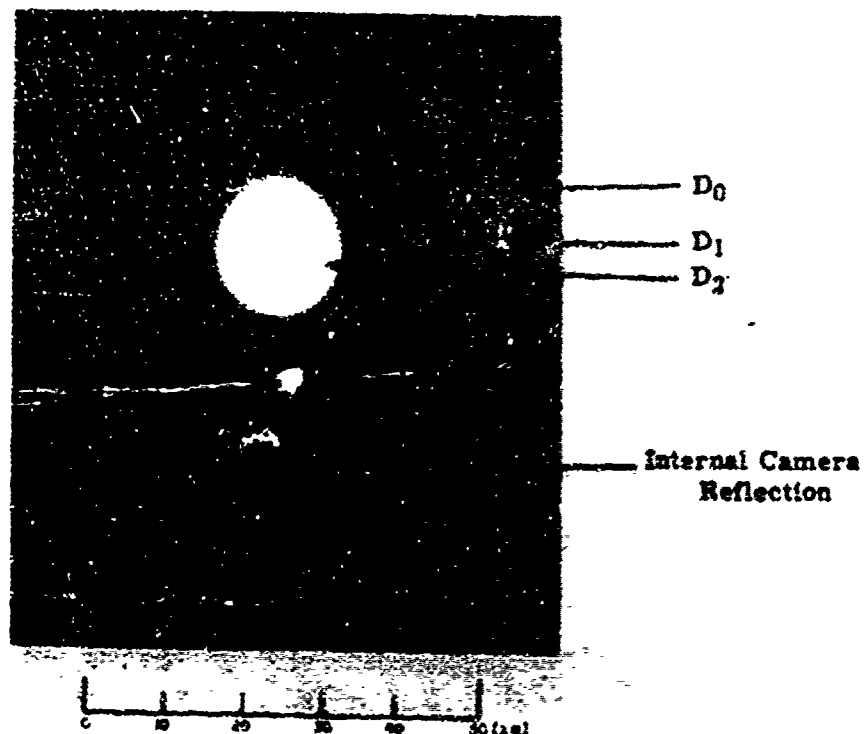


Figure 4.9 Fireball at 50 msec, Station 830.01,
70-mm Maurer M-4 camera, Shot Teak.

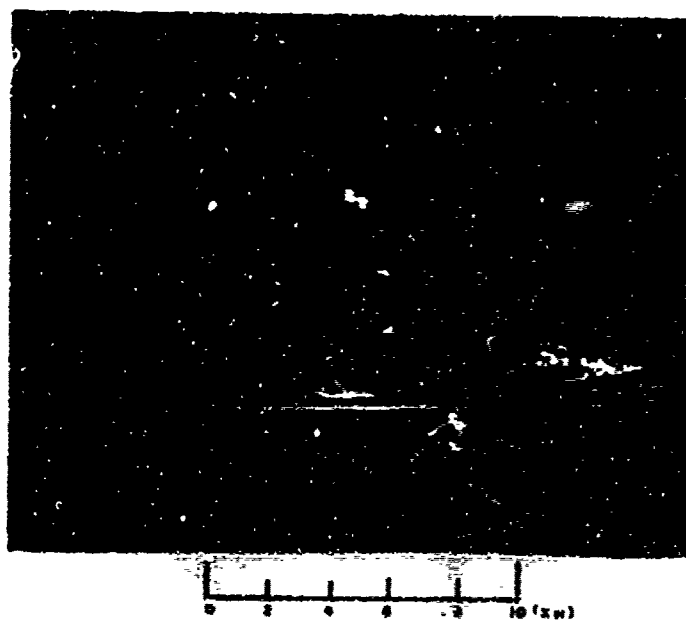


Figure 4.10 Fireball at 251 msec Station 830.01,
35-mm Fastax camera, Shot Teak.

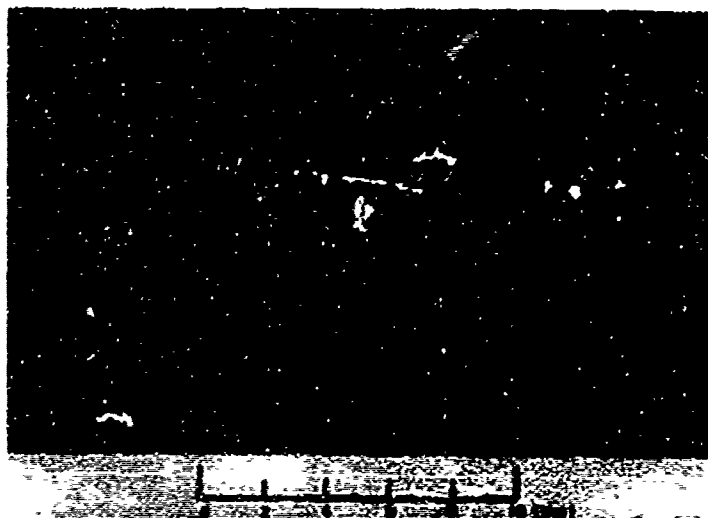


Figure 4.11 Fireball at 547 msec, Station 830.01,
35-mm FX camera, Shot Teak.

Rising Shock-like Front



Figure 4.12 Fireball at 2.45 seconds, Station 830.01,
70-mm Maurer M-4 camera, Shot Teak.



Figure 4.14 Fireball at 5.15 seconds, Station 830.01,
70-mm Maurer M-4 camera, Shot Tenk.

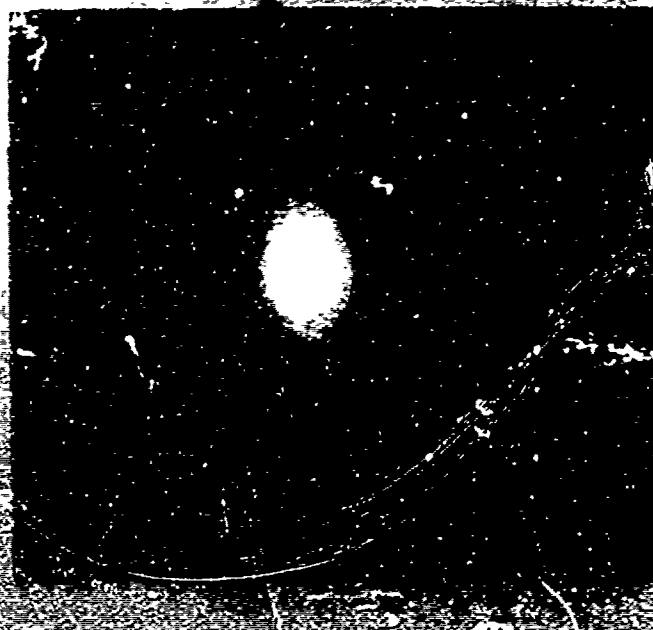
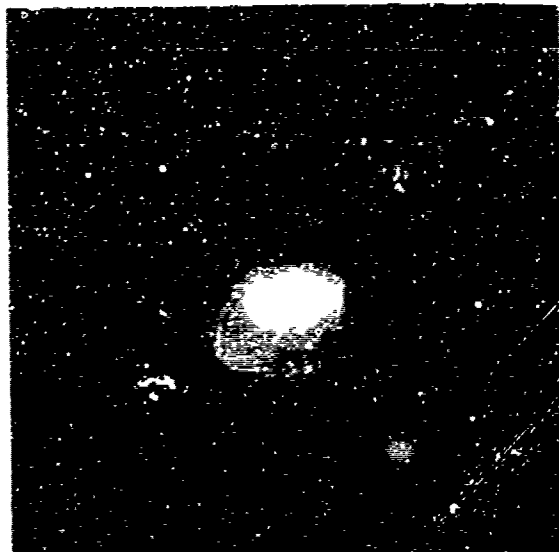


Figure 4.13 Fireball at 3.95 seconds, Station 830.01,
70-mm Maurer M-4 camera, Shot Tenk.



Luminescence
Rising from
Bottom



Figure 4.15 Fireball at 7.55 seconds, Station 530.01,
70-mm Maurer M-4 camera, Shot Teak.

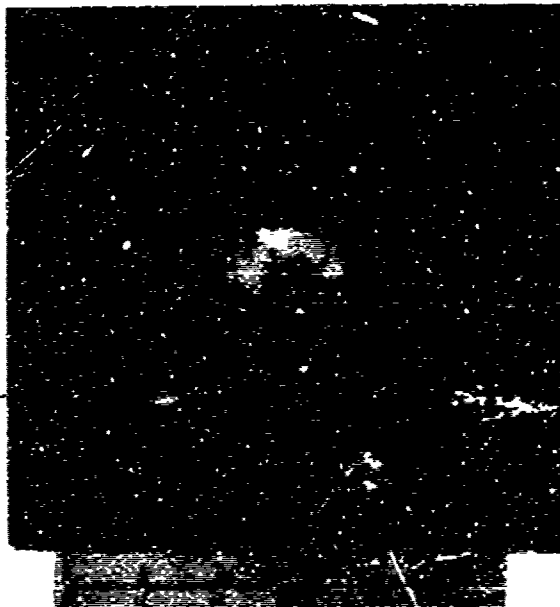


Figure 4.16 Fireball at 10.85 seconds, Station 530.01,
70-mm Maurer M-4 camera, Shot Teak.

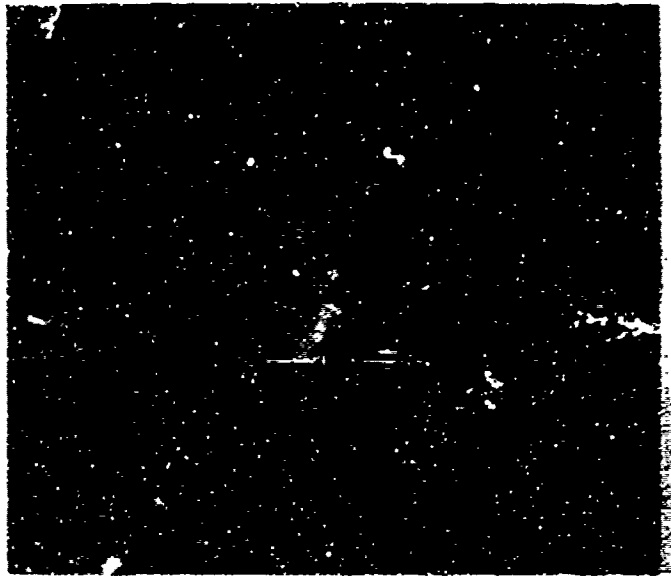


Figure 4.17 Fireball at 19.85 seconds, Station 839.01,
70-mm Maurer M-4 camera, Shot Teak.



Figure 4.18 Fireball at approximately 3 seconds,
Station 831, 70-mm Hulcher H-11 camera, Shot Teak.

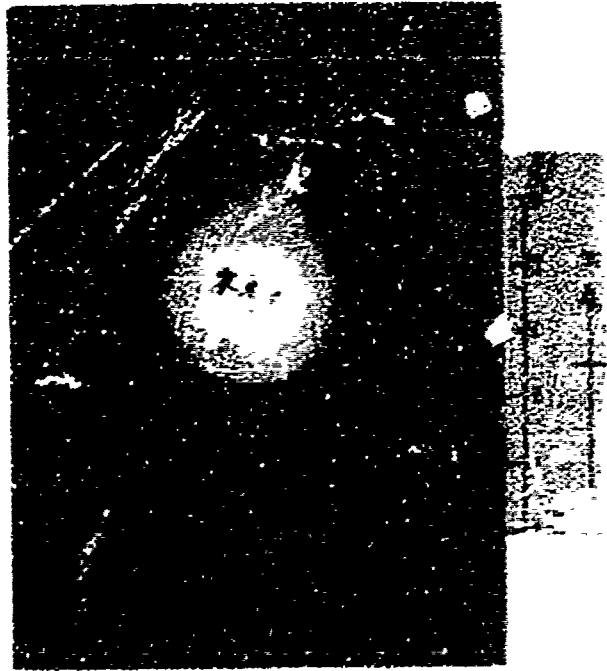


Figure 4.20 Fireball at approximately 5 seconds,
Station 631, 76-mm Bulcher H-10 camera, Shot Peak

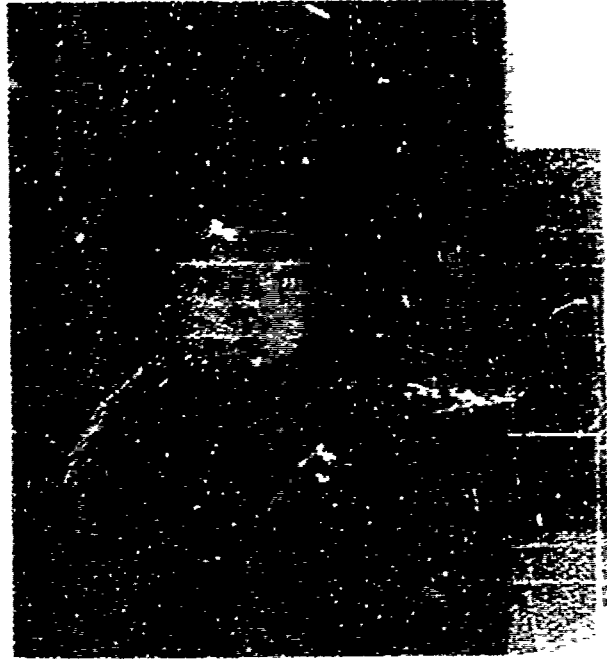


Figure 4.19 Fireball at approximately 4 seconds,
Station 631, 70-mm Bulcher H-10 camera, Shot Peak

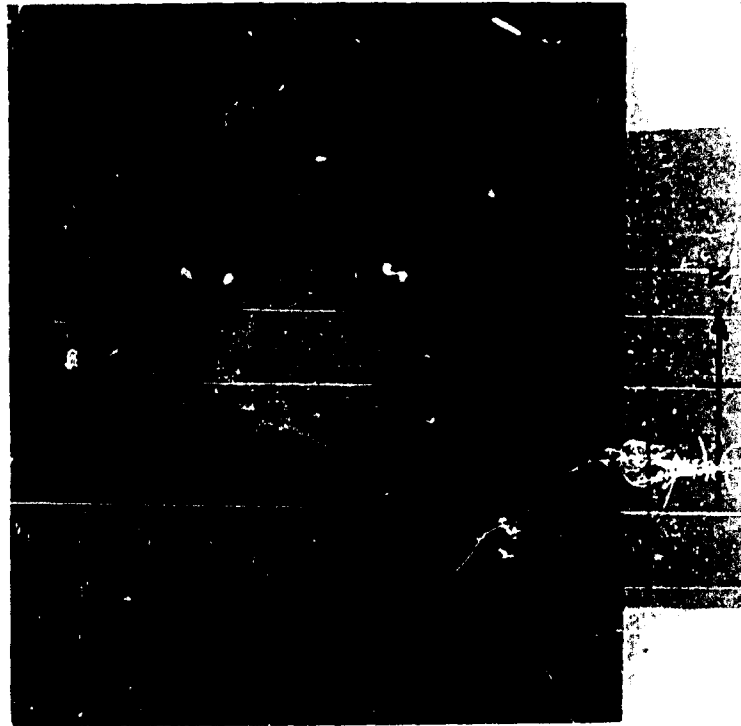


Figure 4.21 Fireball at approximately 6 seconds,
Station 831, 70-mm Hulcher H-10 camera, Shot Teak.

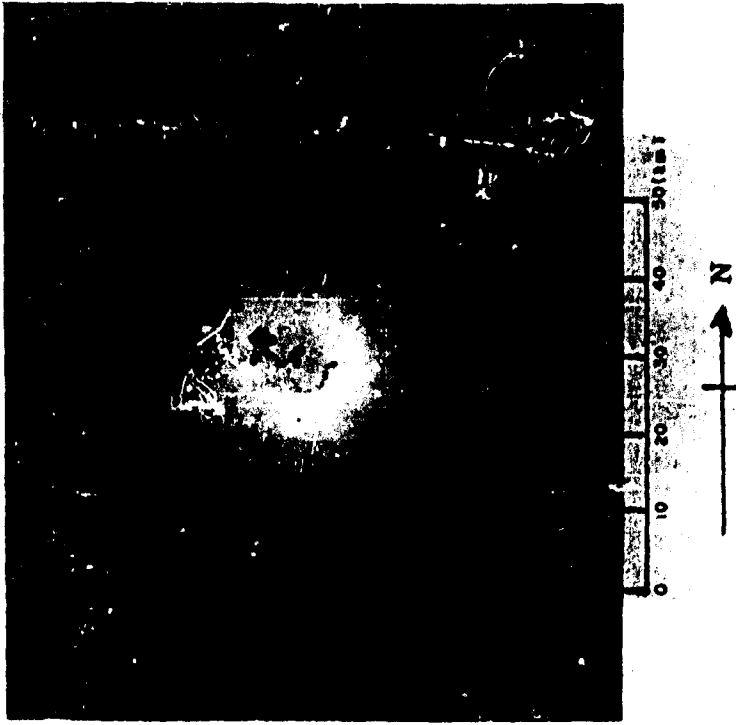


Figure 4.22 Fireball at approximately 7 seconds,
Station 831, 70-mm Hulcher H-10 camera, Shot Teak.

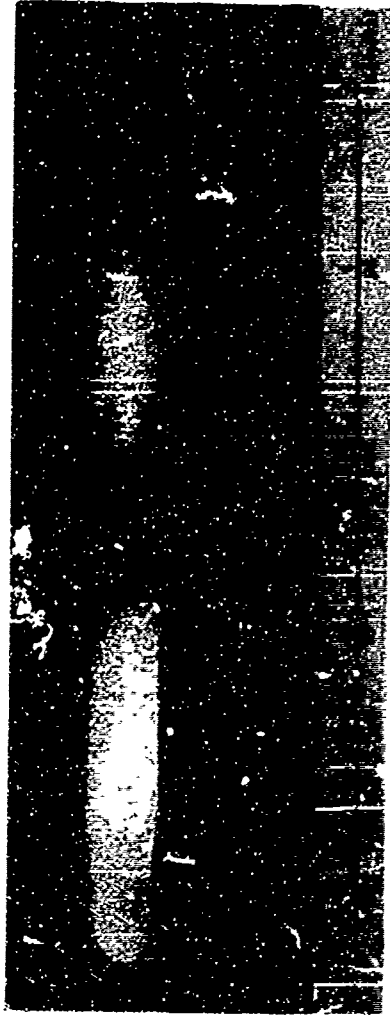


Figure 4.23 Streak record, 70-mm Streak-STR-6 (filter ND-1), Station 830.02 (horizontally mounted), Shot Teak.



Figure 4.24 Streak record, 70-mm Streak-STR-4 (filter ND-4), Station 830.02 (vertically mounted), Shot Teak.

Figure 4.25 Streak record, 70-mm Streak-STR-4 (filter ND-4), Station 830.02 (vertically mounted), Shot Teak.



Figure 4.25 Streak Record, 70-rim Streak-STR-5 (filter ND-3),
Station 830.02 (horizontally mounted), Shot Teak.



Figure 4.26 Streak record, 70-rim Streak-STR-2 (filter ND-3),
Station 830.01 (horizontally mounted), Shot Teak.

Chapter 5

SHOT ORANGE: CAMERA INSTRUMENTATION, ANALYSIS, AND RESULTS

5.1 INSTRUMENTATION AND CAMERA OPERATION

The camera stations for Orange were the same as for Teak. All cameras functioned properly, but cloud cover prevented the cameras at Johnston Island from obtaining usable records, thus, analysis of the Orange fireball growth was restricted to the records from the aircraft stations. The aircraft positions and survey data are presented in Figures 5.1 and 5.2. The photo plans and photo loading charts are contained in Appendix D.

5.2 RESULTS

The diameter versus time plot for Orange is presented in Figure 5.3. Where disagreement in streak record curves is significant, each curve is plotted separately and labeled with station number and filter rating. Microphotometric measurements of Orange made on the Yucca streak records show that the disagreement among records is attributable to the filters employed and the method of photographic processing used. Agreement among records from cameras using filters of the same value was much better than in the case of Yucca, probably because of the higher light-intensity levels of the Orange detonation, because the filters used on the Orange cameras were of lower density values than those chosen for Yucca. Enough light passed the filters to present an image that was easily measured despite image density differences introduced by field-processing techniques used on the streak records.

The Orange fireball exhibits vertical asymmetries at early times similar to those noticed on the Teak records (Figure 5.6), but by 250 msec the configuration of the fireball image is essentially circular. At the lower altitude of the Orange detonation, the differential in air density between the top and bottom of the fireball is much less than that for Shot Teak, so the asymmetry is not as pronounced or as persistent as was noted during Teak.

The emulsion of each of the first three frames of the 24 frames/sec Mitchell camera records was burned, and the fourth frame had a solarized image, giving an indication of the high intensity level of the early light from the detonation. Diameters calculated from measurements of these frames were in poor agreement with diameters from other films at comparable times. The diameters calculated from subsequent frames were in good agreement, thus, the measurements from the first four frames of each Mitchell record were not considered representative of the Orange diameter-time growth and were excluded from the plot.

At approximately 20 msec, a core is discernible on the 35-mm Fastax record. This core assumes a circular shape (Figure 5.7) and rises to the top of the fireball, where it appears to rise out of the top of the fireball envelope (Figure 5.16). A large luminescent halo effect starting at the bottom of the envelope (Figures 5.7 through 5.12) appears

around the core at approximately 286 msec. As the core rises, the halo diameter appears to diminish until it converges into the core. At very late times, the bottom of the envelope seems to rise, creating a vortexlike appearance (Figure 5.16).

At late times, an aurora, less pronounced than that associated with Shot Teak, is discernible on 70-mm Orange records.

The spot which appears on the face of the Orange envelope (Figures 5.10 through 5.12) is discernible in photographs taken from both airborne stations and has the proper northerly orientation to indicate a possible association with the vehicle launched at Johnston Island.

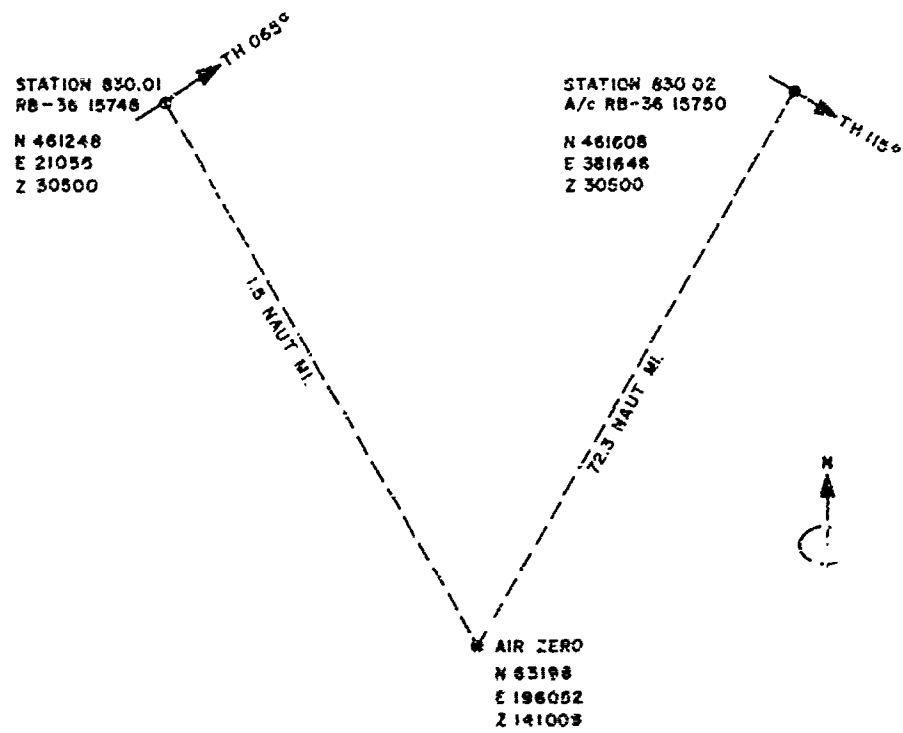
Inspection of the aircraft records of the Orange debris torus shows it to be nearly circular over the first few seconds.

If the toroid were assumed to be circular in a plane parallel to the surface of the earth, as the Teak toroid was, the Orange toroid should be more nearly elliptical than Teak's appeared in the aircraft records, because the elevation angle of Orange above the horizontal is half that of Teak. This is not the case; in fact, the opposite is true. (Compare Figures 4.10, 4.11, and 4.12 with Figures 5.7, 5.8, 5.9, 5.12, and 5.13). This would lead to the assumption that the Orange torus is circular in a plane that is close to being perpendicular to the surface of the earth.

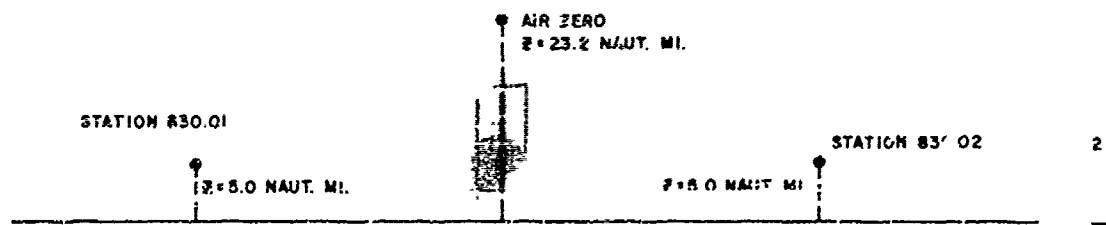
Two explanations of this paradoxical observation are offered. (1) The orientation of the early torus might be a function of the axis of the missile at detonation time, although this is considered highly improbable. Presumably, the Teak missile was still climbing at detonation; whereas the Orange missile, whose track was some 20 nautical miles down and 20 nautical miles up from its launch point, might have detonated at apogee. From this difference in positions, it might be inferred that the early torus was propagated in a plane perpendicular to the track axis. (2) The mechanisms that effect the rising vortexing action common to all bomb debris could have influenced the Teak debris at much earlier times than it influenced the Orange debris. This inference does not, however, explain the apparent hole in the Early Orange debris.

A third possibility, a discussion of which is beyond the scope of this report, is the interaction between the fireball plasma and the earth's magnetic field.

Photographic records obtained during the Orange detonation are presented in Figures 5.4 through 5.20.



PLAN VIEW



SIDE VIEW

Figure 5.1 Aircraft positions relative to burst, Shot Orange.

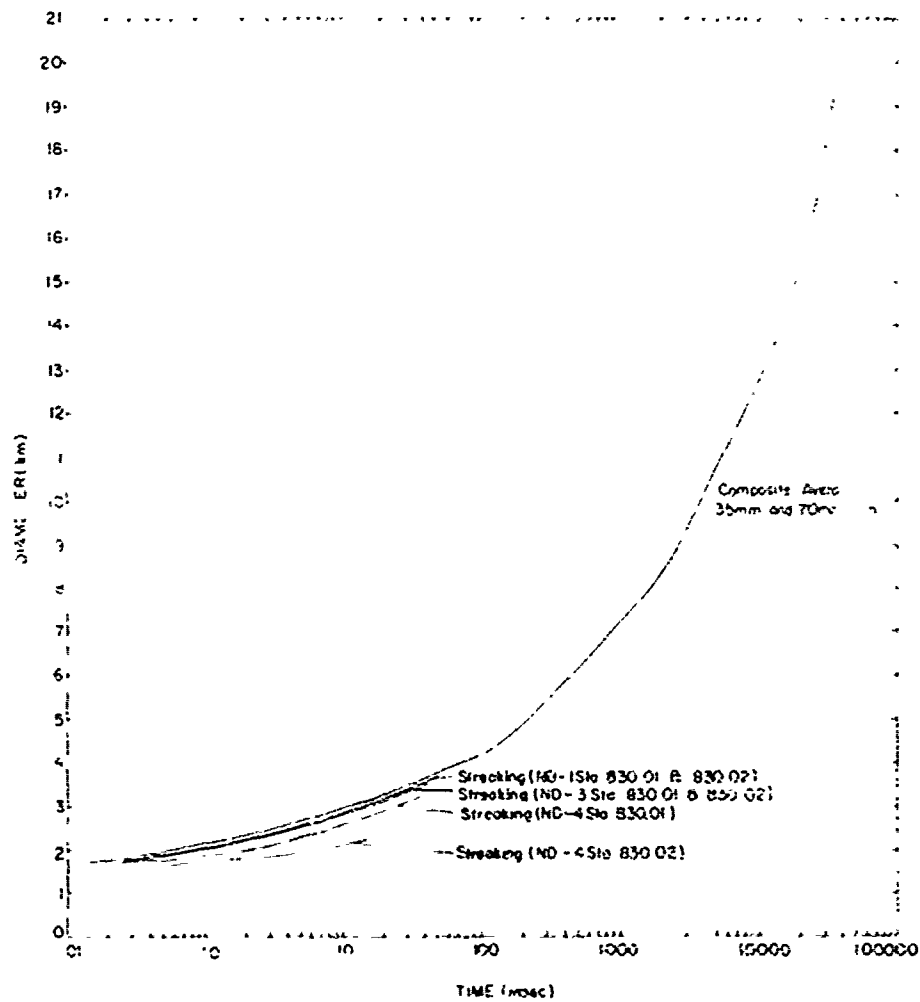


Figure 5.3 Diameter-time plot, Shot Orange.



Camera
Lens
Flare

Figure 5.4 Fireball at 0.58 msec, Station 830.01,
36-mm Fastax FF-1 camera, Shot Orange.



Camera
Lens
Flare

Figure 5.5 Fireball at 9.68 msec, Station 830.01,
35-mm Fastax FF-1 camera, Shot Orange.



Figure 5.6 Fireball at 52 msec, Station 830.01,
35-mm Fastax FF-1 camera, Shot Orange.

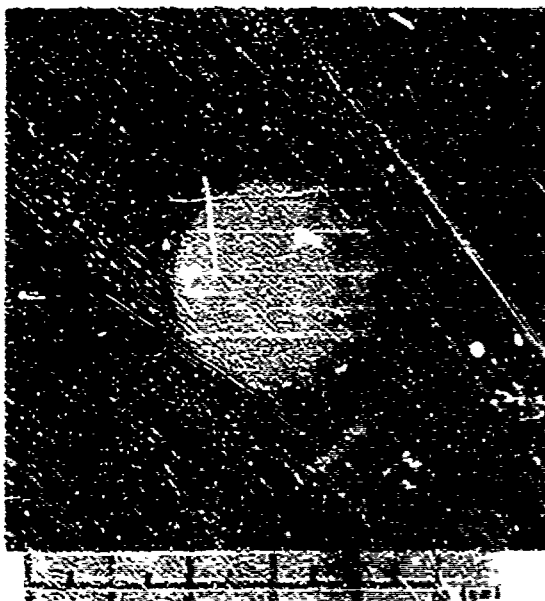


Figure 5.7 Fireball at 286 msec, Station 830.02,
35-mm Fastax FF-2 camera, Shot Orange.

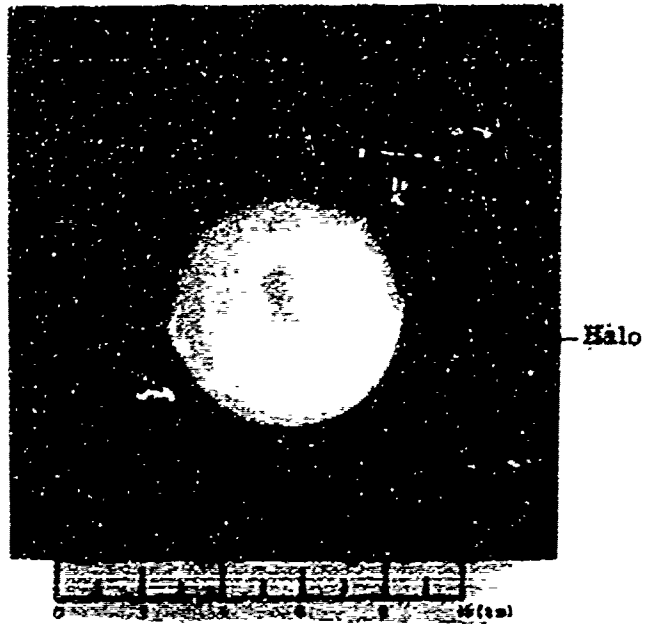


Figure 5.8 Fireball at 430 msec, Station 830.02,
35-mm Fastax FF-2 camera, Shot Grange.

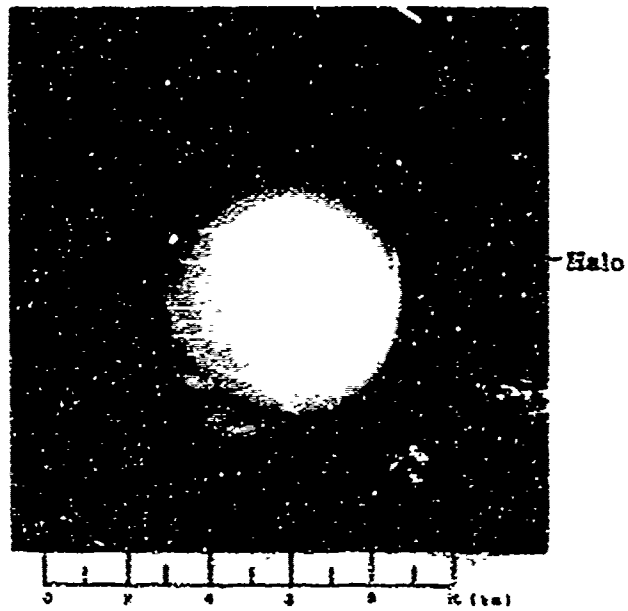


Figure 5.9 Fireball at 596 msec, Station 830.02,
35-mm Fastax FF-2 camera, Shot Orange

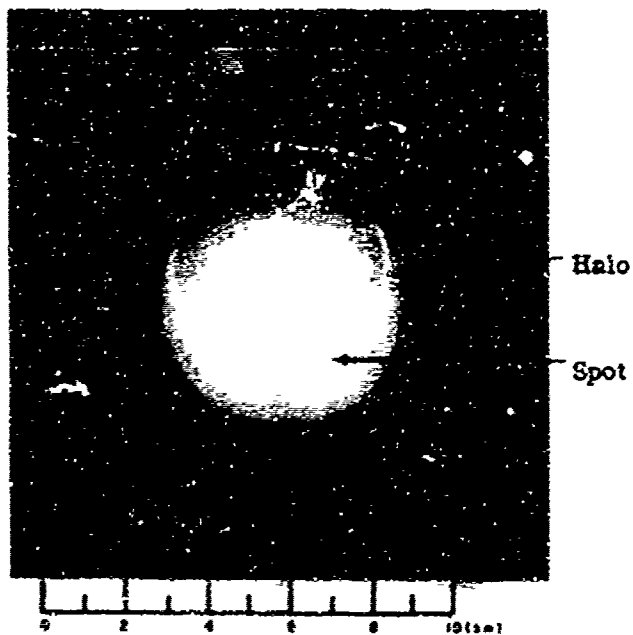


Figure 5.10 Fireball at 803 msec., Station 839.02, 35-mm FF-2 camera, Shot Orange. (Note circular torus.)

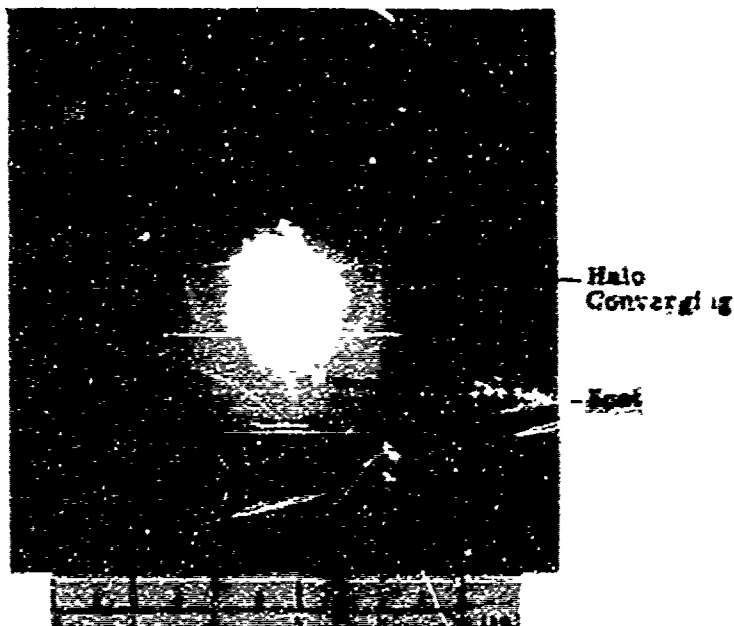
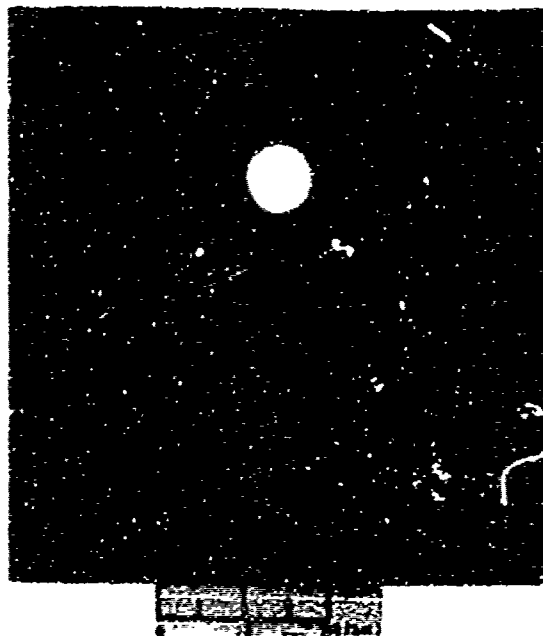


Figure 5.11 Fireball at 969 msec, Station 830.02, 35-mm Fastax FF-2 camera, Shot Orange. (Note circular torus.)



Ball
Converges
Into Debris

Figure 5.12 Fireball at 1.58 second, Station 830.02,
35-mm Fastax FF-2 camera, Shot Orange.



Internal
Camera
Reflection

Figure 5.13 Fireball at 2.142 seconds, Station 830.02,
70-mm Maurer M-7 camera, Shot Orange.



Internal
Camera
Reflection

Figure 5.14 Fireball at 9.94 seconds, Station 830.02
70-mm Maurer M-7 camera, Shot Orange.

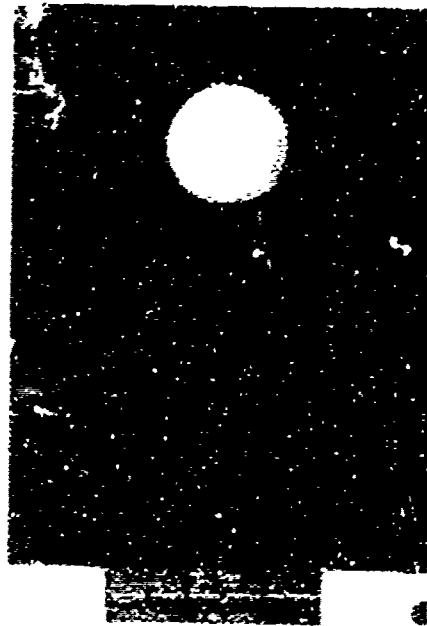


Figure 5.15 Fireball at 15.34 seconds,
Station 830.02, 70-mm Maurer M-7
camera, Shot Orange



Figure 5.16 Fireball at 25.74 seconds,
Station 330.02, 70-mm Maurer M-7
camera, Shot Orange

S3

SECRET

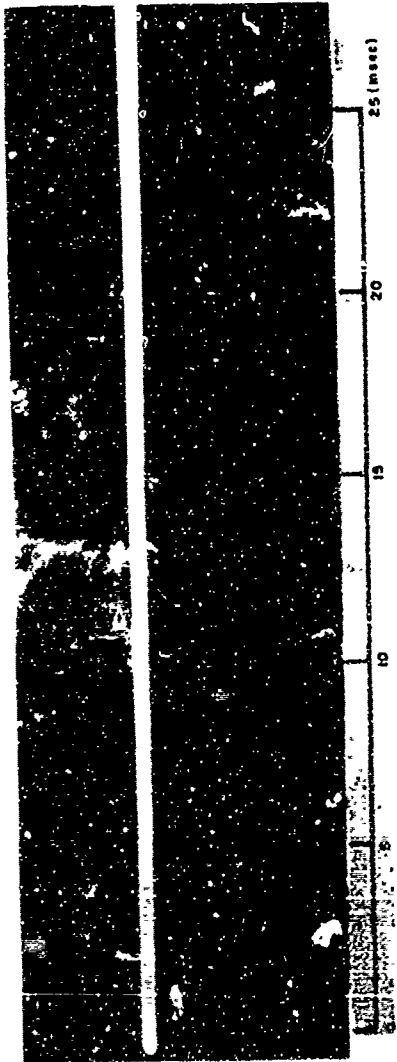


Figure 5.17 Streak record, 70-mm Streak-STR-6 (filter ND-1), Station 830.02 (horizontally mounted), Shot Orange.

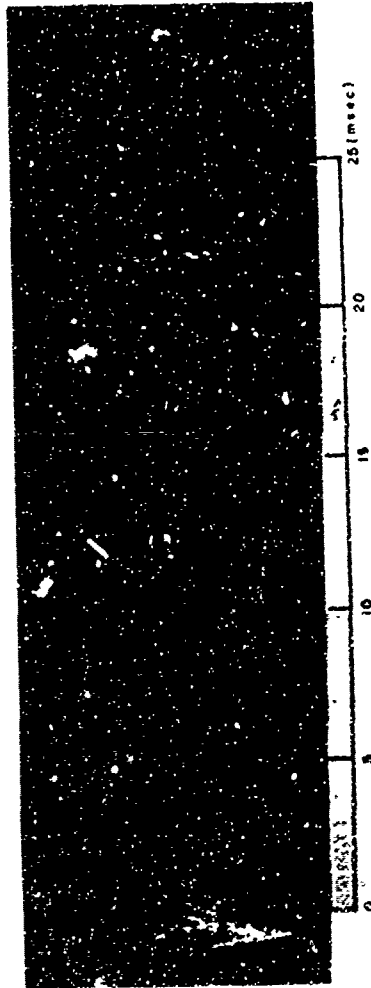


Figure 5.18 Streak record, 70-mm Streak-STR-4 (filter ND-4), Station 830.02 (vertically mounted), Shot Orange.



Figure 5.19 Streak record, 70-mm Streak-STR-2 (filter ND-3),
Station 830.01 (horizontally mounted), Shot Orange.



Figure 5.20 Streak record, 70-mm Streak-STR-5 (filter ND-3),
Station 830.02 (horizontally mounted), Shot Orange.

Station 830.02 (horizontally mounted), Shot Orange.

Chapter 6

RECOMMENDATIONS

6.1 GENERAL

It is highly recommended that further photogrammetric analysis of the three Hardtack high-altitude detonations be pursued. Rate of rise of the burst phenomena, nature and dimensions of the aurora, and the light characteristics of the various phenomena are some of the areas that show promise of yielding useful data. The Hardtack high-altitude data and measurements from previous aerial tests should be evaluated in an attempt to determine scaling laws and to ascertain partition of energy data.

For future high-altitude tests, photographic coverage should be considerably expanded, with emphasis directed to obtaining better time resolution and additional significant phenomenological data by using more cameras and a wider variety of film types and lenses. The use of stabilized platforms for the airborne cameras and a fast exposure compensating system would contribute significantly to the improvement of detonation records. It is also highly recommended that extreme care be exercised in obtaining accurate air flight data. It seems imperative to employ a tracking system whereby the cameras are aimed at the missile continuously during its flight. Dependence on ground-camera systems is unfruitful; at least three aircraft should be used, as outlined below.

6.2 DETONATION COVERAGE

In addition to the two aircraft stations and one ground station used for Teak and Orange, it is recommended that a third aircraft station be employed to permit a better coverage of events and a more detailed analysis of the spatial relationships of the various phenomena recorded. This third station would also serve as a backup to the other two.

At least two additional ground or shipboard stations are recommended for fireball coverage. One station should be located about 1,000 miles from the detonation, and the other at a convenient distance between the launch point photo station and the 1,000-mile station. For Shot Teak, EG&G had a station at Mt. Haleakala on the island of Maui, State of Hawaii. The purpose of the station was to make long-range light measurements of the high-altitude detonations. The Maui station was approximately 800 nautical miles from the Teak detonation. Excellent 35-mm color still films of Teak were recorded from that station, indicating the valuable technical potential of long-range photography of extremely high-altitude detonation phenomenology (Reference 5).

Extensive cloud cover over more than one ground station and/or any of the aircraft stations should be sufficient reason for shot postponement.

High-speed streak cameras capable of at least 0.1 μ sec resolution are recommended for complete coverage of the first millisecond of fireball growth. High-speed framing cameras, capable of 25,000 frames/sec or more, should be used to obtain discrete pictures of fireball growth through the first 1.5 μ sec. Electronic cameras should be

employed at one ground station for accurate early-time data, permitting precise determination of zero frame time on motion-picture film records. Rate-of-rise records should be obtained by aircraft cameras mounted in pairs, one aimed at the expected detonation point and the other aimed above it to record cloud rise beyond the field of view of the first camera.

Cameras with extra-wide fields of view are recommended for the recording of sky glow effects from the detonation.

6.3 AURORAL CONJUGATE POINT COVERAGE

Photographic coverage should be provided for the area of the expected auroral conjugate point. At least two airborne photo stations and two ground stations should be instrumented for recording auroral effects in the area. Coverage at the conjugate point would include timed photographs to document aurora arrival time, configuration, and drift. In addition, these stations could provide long-range coverage of the sky glow from the detonation area.

6.4 FILM PROCESSING

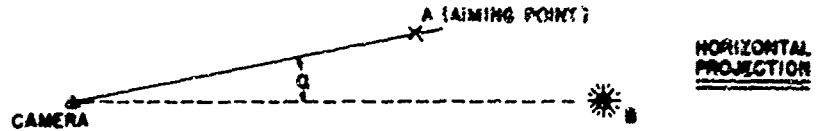
Facilities should be made available to provide adequate control of the processing of all films made. If such facilities cannot be provided in the field, then, in the interest of preserving irreplaceable photometric data, the films should be transported to a location with the necessary equipment to insure proper controlled processing of the films. Under no circumstances should hand processing techniques be employed.

Appendix A

SAMPLE CAMERA DATA AND FILM MEASUREMENTS

CAMERA DATA & CALCULATIONS

FILM NO. 50880	STATION NO. 230.01	TEST Yucca	CALCULATED BY: RS
CAMERA NO. STR #3	EQ. AP.		DATE: 3/19/58



A. $R^{\circ}/A = CB_h \cos \alpha \cos \beta + (H_B - H_C) \sin \beta$

$\alpha = 5^{\circ}08'$	$\beta = 34^{\circ}38'$	$H_B = 25511.29 \text{ m}$
$\cos \alpha = 0.995863$	$\cos \beta = 0.822808$	$H_C = 10973.93 \text{ m}$
$CB_h = 21497.90 \text{ m}$	$\sin \beta = 0.568322$	$\Delta H = 14537.36 \text{ m}$
$CB_h \cos \alpha \cos \beta = 17617.19 \text{ m}$	$\Delta H \sin \beta = 8432.97 \text{ m}$	$R^{\circ}/A = 250^{\circ} 16 \text{ m}$

B. FOCAL LENGTH 149.06 mm (Lens Serial No. 729988)

C. MAGNIFICATION FACTOR (meters/in.) 4438.90

D. ZERO TIME CORRECTION

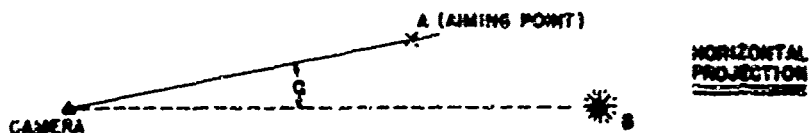
STREAK CALCULATION SHEET, FILM NUMBERS: 581

Shot Yucca, Streak Camera Number 3 Speed at zero ft. 18.23 ft./sec.

Time		Diameter		Time		Diameter	
microns (film)	msec	microns (film)	n	microns (film)	msec	microns (film)	meters
725	0.13	331	53.17	96,089	17.29	1,345	236.39
2,679	0.51	434	76.27	100,499	18.08	1,360	239.03
4,150	0.74	490	86.12	104,773	18.85	1,377	242.02
5,520	0.99	547	96.14	108,993	19.61	1,414	248.52
6,879	1.23	580	101.94	113,054	20.34	1,388	243.95
7,950	1.43	611	107.91	117,100	21.07	1,391	244.48
9,424	1.69	656	115.29	121,016	21.78	1,372	241.14
11,655	2.09	696	122.32	125,023	22.50	1,400	246.06
14,100	2.53	751	131.59	129,106	23.23	1,432	251.68
16,310	2.93	802	140.95	133,062	23.95	1,421	248.75
18,490	3.32	811	142.54	137,029	24.66	1,463	257.13
21,128	3.80	868	152.55	141,954	25.38	1,437	252.56
23,769	4.17	885	155.34	145,524	26.19	1,445	253.97
25,511	4.53	913	160.16	149,958	26.99	1,476	259.12
27,563	4.99	942	165.35	153,954	27.71	1,460	256.60
31,661	5.69	991	174.17	158,147	28.16	1,456	255.90
34,886	6.15	1,030	181.56	162,049	29.16	1,474	259.67
37,142	6.68	1,085	188.29	166,330	29.90	1,450	254.85
40,800	7.23	1,093	193.16	170,273	30.61	1,474	259.07
43,068	7.75	1,083	191.41	174,177	31.35	1,445	253.97
46,999	8.31	1,153	198.13	177,980	32.05	1,429	251.16
47,773	8.52	1,147	201.50	182,075	32.77	1,315	209.22
53,335	9.59	1,188	208.30	186,187	33.51	1,474	259.07
53,856	10.23	1,203	211.43	190,233	34.24	1,416	249.22
61,320	11.03	1,331	216.36	194,308	34.97	1,345	236.39
64,017	11.98	1,331	216.71	198,096	35.65	1,395	245.18
68,074	12.43	1,340	221.45	202,264	36.40	1,375	232.88
73,053	13.14	1,375	224.09	206,274	37.12	1,308	229.89
77,169	13.85	1,359	230.06	210,069	37.81	1,358	239.68
81,321	14.62	1,332	232.09	214,042	38.52	1,366	240.08
86,153	15.32	1,319	231.82	218,114	39.26	1,438	247.47
89,709	16.0	1,345	236.04	222,010	39.96	1,345	236.39
92,143	16.68	1,353	237.09	225,259	40.54	1,494	260.62

CAMERA DATA & CALCULATIONS

FILM NO. 54303	STATION NO. 830.01	TEST ORANGE	CALCULATED BY: RS
CAMERA NO. 35FF No. 1	EQ. AP.		DATE: 12/5/58



A. $R/A = CB_H \cos e \cos \beta + (H_B - H_C) \sin \beta$		
$e = 0^{\circ}00'$	$\beta = 12^{\circ}11'$	$H_B = 42380 \text{ m}$
$\cos e = 1.00000$	$\cos \beta = 0.97748$	$H_C = 3907 \text{ m}$
$CB_H = 132527 \text{ m}$	$\sin \beta = 0.21104$	$\Delta H = 38683 \text{ m}$
$CB_H \cos e \cos \beta = 129542 \text{ m}$	$\Delta H \sin \beta = 7108 \text{ m}$	$R/A = 136650 \text{ m}$
B. FOCAL LENGTH 101.16mm (Lens Serial No. B12678)		

C. MAGNIFICATION FACTOR (meters/in.)	34310
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D. ZERO TIME CORRECTION

DIAMETER MEASUREMENTS

SHOT ORANGE

FILM NO 54303

Fr. No.	Mag.	R ₁	R ₂ in.	R ₃	R _{avg}	FLEXO WRITER	
						D _{avg} (m)	t (ms)
0000	18.33	0102	0112		107	1889.2	0.56
0001		0119	0125		122	2165.5	1.13
0002		0125	0130		129	2289.7	1.70
0003		0134	0136		135	2396.2	2.27
0004		0138	0140		139	2467.2	2.84
0005		0144	0144		143	2538.2	3.41
0008		0148	0153		151	2680.2	5.12
0010		0153	0156		155	2751.2	6.26
0012		0157	0160		159	2822.2	7.40
0014		0160	0164		162	2875.4	8.54
0016		0164	0167		166	2946.4	9.69
0018		0169	0171		170	3017.3	10.82
0020		0170	0172		171	3035.2	11.98
0025		0175	0179		177	3141.7	14.21
0030		0179	0182		181	3212.7	17.66
0035		0185	0185		187	3319.2	20.5
0040		0187	0193		190	3372.4	23.3
..		0194	0197		196	3478.8	26.6
0050		0195	0199		199	3485.7	29.01
0055		0199	0202		201	3567.7	31.91
0060		0201	0205		203	3593.2	34.51
0065		0202	0207		205	3638.7	37.61
0070		0207	0208		208	3682.0	40.42
0075		0209	0210		209	3708.7	43.31
0080		0209	0212		211	3745.2	46.18
0085		0210	0216		213	3780.7	49.01
0090		0211	0214		213	3785.7	51.91
0095		0214	0217		214	3833.8	54.71
0100		0216	0218		217	3851.7	57.55
0110		0218	0220		219	3897.2	63.15
0120		0218	0224		222	3940.4	66.76
0130		0224	0227		225	3993.7	74.36

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DATE 2/25/58 DATE _____

REMARKS:

DIAMETER MEASUREMENTS

SHOT ORANGE

FILM NO. 54303
(Page 2)

Fr. No.	Mag.	R ₁	R ₂ in	R ₃	R _{avg}	FLEXOWRITER	
						D _{avg} (m)	t (ms)
0140	19.33	0225	0230		228	4046.9	79.86
0150		0227	0231		229	4064.7	85.56
0160		0228	0234		231	4100.2	91.16
0170		0229	0237		233	4135.7	96.76
0180		0230	0240		235	4171.2	102.35
0190		0232	0242		237	4206.7	107.96
0200		0235	0245		240	4259.9	113.56
0210		0239	0247		243	4313.2	119.14
0220		0242	0246		244	4330.9	124.76
0230		0243	0248		246	4366.4	130.36
0240		0247	0250		249	4420.0	135.98
0250		0249	0254		252	4472.9	141.56
0260		0251	0252		252	4472.9	147.16
0270		0253	0256		255	4526.2	152.76
0280		0254	0259		257	4561.7	158.36
0290		0257	0262		260	4614.9	163.96
0300		0260	0265		263	4668.1	169.56
0310		0263	0265		264	4685.9	175.16
0320		0266	0268		267	4739.1	180.76
0330		0270	0271		271	4810.1	186.36
0340		0270	0274		272	4827.9	191.96
0350		0272	0277		275	4861.1	197.56
0360		0275	0280		278	4934.4	203.16
0370		0278	0281		280	4970.0	208.76
0380		0277	0286		282	5005.4	214.36
0390		0280	0287		284	5040.9	219.96
0400		0283	0288		286	5076.4	225.56
0410		0287	0290		289	5129.6	231.16
0420		0289	0292		291	5155.1	236.76
0430		0291	0294		293	5200.6	242.36
0440		0291	0295		293	5200.6	247.96
0450		0293	0298		295	5226.1	253.56

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DATE 2/25/59 DATE _____

REMARKS:

DIAMETER MEASUREMENTS

SHOT ORANGE

FILM NO. 54303
(Page 3)

Fr. No.	Mag.	R ₁	R ₂ in.	R ₃	D _{avg}	FLEXOMETER	
						D _{avg} (m)	t (ms)
0460	19.33	0296	0288		297	5271.6	256.36
0470		0297	0301		299	5307.1	262.36
0480		0299	0302		301	5342.6	267.76
0490		0302	0303		303	5378.1	273.16
0500		0307	0307		305	5413.6	278.56
0510		0304	0309		307	5449.1	283.96
0530		0310	0313		312	5537.8	294.76
0550		0312	0315		314	5573.4	305.56
0575		0315	0321		318	5644.4	319.06
0600		0317	0324		321	5697.6	332.56
0625		0318	0327		323	5733.1	347.86
0650		0321	0330		326	5786.4	359.06
0675		0324	0333		329	5839.6	372.36
0700		0326	0335		331	5875.1	385.56
0725		0329	0336		333	5910.6	398.56
0750		0331	340		336	5963.9	411.56
0775		0333	344		339	6017.2	424.56
		0334	348		342	6070.4	437.56
0825		0336	352		344	6105.9	458.56
0850		0338	354		346	6141.4	463.56
0875		0340	356		348	6176.9	476.56
0900		0342	356		349	6184.6	489.56

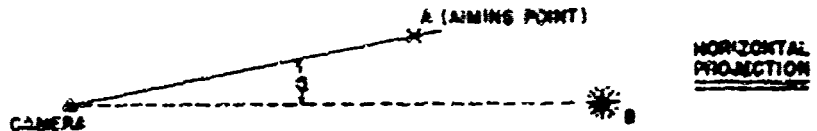
READ BY R. C. S. J. C. TYPED BY _____

DATE 2/25/59 DATE _____

REMARKS:

CAMERA DATA & CALCULATIONS

FILM NO. 54151	STATION NO. 220 01	TEST Teak	CALCULATED BY: RS
CAMERA NO. M-1	EQ. AP.		DATE: 12/3/58



A. $R^0/A = CB_h \cos \epsilon \cos \beta + (H_b - H_c) \sin \beta$

$\epsilon = 0^\circ 00'$	$\beta = 26^\circ 36'$	$H_b = 76315 \text{ m}$
$\cos \epsilon = 1.00000$	$\cos \beta = 0.89153$	$H_c = 9287 \text{ m}$
$CB_h = 118933$	$\sin \beta = 0.45295$	$\Delta H = 67018 \text{ m}$
$CB_h \cos \epsilon \cos \beta = 106032 \text{ m}$	$\Delta H \sin \beta = 30356 \text{ m}$	$R^0/A = 136.9 \text{ m}$

B. FOCAL LENGTH 34.77 mm (Lens Serial No. 3248077)

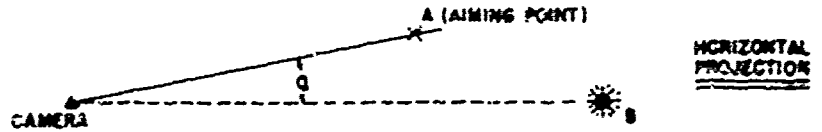
C. MAGNIFICATION FACTOR (meters/in.) 95632

D. ZERO TIME CORRECTION

Horizontal Diameter-Time TEAK Film No. 54151				NAME RCS-CJK			DATE 4/58
Frame	D _i (mm)	D ₁ (mm)	D ₃ (mm)	D ₃ (mm)	D ₅ (mm)	D ₅ (mm)	Time (msec)
0	3.83	15.02	-	-	-	-	14.0
1	3.85	15.10	-	-	-	-	56.9
2	3.93	15.42	-	-	-	-	99.7
3	4.00	15.69	-	-	-	-	142.6
4	4.05	15.89	-	-	-	-	185.4
5	4.10	16.03	-	-	-	-	228.3
8	4.35	17.06	-	-	-	-	356.9
10	4.53	17.77	2.10	8.24	-	-	442.6
12	4.63	18.16	2.20	8.63	-	-	528.3
14	4.73	18.55	2.40	9.41	-	-	614.0
16	4.83	18.95	2.55	10.00	-	-	699.8
18	5.00	19.61	2.60	10.20	-	-	785.5
20	5.08	19.93	2.80	10.92	-	-	871.2
22	5.20	20.40	3.00	11.77	-	-	956.9
24	5.30	20.70	3.10	12.15	2.00	7.85	1042.6
26	5.40	21.18	3.20	12.55	2.10	8.24	1128.4
28	5.50	21.57	3.20	12.55	2.15	8.43	1214.1
30	5.60	21.97	3.33	13.06	2.20	8.63	1300.0
35	5.83	22.87	3.80	14.91	2.30	9.02	1485.7
40	6.10	23.93	4.15	16.26	2.20	8.63	1671.4
45	6.30	24.71	4.45	17.46	2.40	9.41	1942.7
50	6.50	25.50	4.70	18.44	2.58	10.12	2157.0
55	6.70	26.28	5.00	19.51	2.85	11.18	2371.3
60	6.85	26.87	5.30	20.79	2.95	11.57	2585.6
65	7.00	27.43	5.50	21.97	3.10	12.16	2800.0
70	8.90	27.07	5.90	23.14	3.25	12.75	3014.2
75	6.9	27.45	6.05	23.73	3.34	13.10	3228.5
80	7.1	27.95	6.20	24.32	3.48	13.65	3442.8
85	-	-	6.40	25.10	3.55	13.92	3657.1
90	-	-	6.60	25.89	3.70	14.51	3871.4
95	-	-	6.80	26.57	3.80	14.91	4085.7
100	-	-	6.90	27.07	3.85	15.10	4300.0
105	-	-	6.90	27.07	3.95	15.49	4514.3
110	-	-	-	-	4.05	15.89	4728.6
115	-	-	-	-	4.10	16.02	4943.0
120	-	-	-	-	4.20	16.47	5157.2
125	-	-	-	-	4.30	16.87	5371.5

CAMERA DATA & CALCULATIONS

FILM NO. 54152	STATION NO. 930.01	TEST Teak	CALCULATED BY: RS
CAMERA NO. M-70 #4	EQ. AP.		DATE: 12/3/58



A. $R^{\circ}/A = CB_2 \cos \alpha \cos \beta + (H_B - H_C) \sin \beta$

$\alpha = 0^{\circ}00'$	$\beta = 26^{\circ}56'$	$H_B = 16315 \text{ m}$
$\cos \alpha = 1.00000$	$\cos \beta = 0.89153$	$H_C = 9297 \text{ m}$
$CB_2 = 118933 \text{ m}$	$\sin \beta = 0.45295$	$\Delta H = 67018 \text{ m}$
$CB_2 \cos \alpha \cos \beta = 106052 \text{ m}$	$\Delta H \sin \beta = 30356 \text{ m}$	$R^{\circ}/A = 136408 \text{ m}$

B. FOCAL LENGTH 79.58 mm (Lens Serial No. 4693032)

C. MAGNIFICATION FACTOR (meters/in) 42531

D. ZERO TIME CORRECTION

TEAK Horizontal Diameter-Time Film No. 54152				NAME RCS-CJK			DATE 4/58
Frame	D ₁ (mm)	D ₁ (km)	D ₃ (mm)	D ₃ (km)	D ₅ (mm)	D ₅ (km)	Time (msec)
0	9.2	15.8	-	-	-	-	50
1	10.2	17.5	4.5	7.7	-	-	350
2	11.0	18.9	5.6	9.8	-	-	650
3	11.7	20.1	6.2	10.6	-	-	950
4	12.4	21.3	7.2	12.3	4.3	7.4	1250
5	13.2	22.6	8.2	14.1	4.5	7.7	1550
6	13.8	23.7	9.2	15.8	5.2	8.9	1850
7	14.5	24.9	10.0	17.1	5.6	9.6	2150
8	15.1	25.9	11.0	18.9	5.8	9.9	2450
9	15.5	26.7	11.8	20.2	5.1	10.5	2750
10	16.2	27.8	12.4	21.3	6.4	11.0	3050
11	17.0	29.1	13.2	22.6	6.7	11.5	3350
12	17.5	30.0	13.9	23.8	6.9	11.8	3650
13	18.2	31.2	14.6	25.0	7.3	12.5	3950
14	18.8	32.2	15.3	26.2	7.5	12.9	4250
15	19.3	32.9	15.9	27.3	7.7	13.2	4550
16	19.6	33.6	16.5	28.3	8.0	13.7	4850
17	-	-	16.8	28.6	8.4	14.4	5150
18	-	-	-	-	8.7	14.9	5450
19	-	-	-	-	9.0	15.4	5750
20	-	-	-	-	9.4	16.1	6050

TEAK Film No. 54152		Vertical Diameter-Time			NAME	RCS	DATE	6/59
Frame (No.)	Time (ms)	D ₀ (mm)	P ₁ (mm)	D ₂ (mm)	D ₃ (mm)	D ₄ (mm)	D ₅ (mm)	
0	50	10.7	10.4	10.3	2.1			
1	350	12.0	11.1	10.9	3.5			
2	650	13.0	11.8	11.6	4.5			
3	950		12.8	12.1	5.4		1.4	
4	1250		13.6	12.7	6.3		2.2	
5	1550		14.3		7.1		2.5	
6	1850		14.8		8.0		2.8	
7	2150				8.6		3.1	
8	2450				9.6		3.5	
9	2750				10.6		4.0	
10	3050				11.5		4.2	
11	3350				12.6	5.4	4.6	
12	3650					6.4	5.0	
13	3954					7.1	5.1	
14	4250					7.9	5.1	
15	4550					8.8	5.4	
16	4850					8.6	5.6	
17	5150						5.7	
18	5450						6.0	
19	5750						6.0	
20	6050						6.3	
21	6350						6.3	
22	6650						6.3	

TEAK		Vertical Diameter-Time		NAME		RCS		DATE	
Film No. 54152								6/59	
Frame (No.)	Time (ms)	D ₀ (km)	D ₁ (km)	D ₂ (km)	D ₃ (km)	D ₄ (km)	D ₅ (km)		
0	50	18.3	17.8	17.6	3.6				
1	350	20.6	19.0	18.7	6.0				
2	650	22.3	20.5	19.9	7.7				
3	950		21.3	20.7	9.3				2.4
4	1250		23.2	21.8	10.8				3.8
5	1530		24.5		12.2				4.3
6	1850		25.5		13.7				4.8
7	2130				14.7				5.3
8	2450				16.5				6.0
9	2750				18.2				6.9
10	3050				19.7				7.2
11	3350				21.6		9.3		8.2
12	3650						11.0		8.6
13	3950						12.2		8.7
14	4250						13.5		8.7
15	4550						15.1		9.3
16	4850						16.5		9.6
17	5150								9.8
18	5450								10.3
19	5750								10.3
20	6050								10.8
21	6350								10.8
22	6650								10.8

Appendix B
PHOTO DATA, SHOT YUCCA

STATION NO. I 32.01 EVENT YUCCLA
 STATION TYPE RB-36 1574A BRG 23.00' GZ STA. 42
 DISTANCE GZ 11.6 NM STATION G 1 TILT DATE 2-19-58
N 426553 431544 DIFF. 65394 GZ OBJ. 3.4 POSTED
E 337621 350000 20421 48680
 DISTANCE OBJECT 15.82' 236000 85600

PHOTO PLAN

CAMERA	LENS		FIELD TARGET N/W	AIMING		POWER		MARKER		RELAT	PLAN	PUB. POST	REMARKS	
	NO. / S/N	FOC. / INCH		ORJCT	M	V	VOLTS	SWITCH	TIME					TYPE
705TR	100	152	37.50	BURST	2.00	3433	34DC	-	2.25	2.00	3.5	-	MF	8.3
705TR														
705TR														
35FE	1000	102	42.37				12.800	-						
M-1	24	35	42.37				2800	30°	1.5	12.7	3.5	-		
M-20	3 1/4	80	56.61	24.20			1/2000	4.10				-	EX	
5470	1/4	12.5	57.44				1/25	4.10				-	ME	
55F	64	18.5	48.77				1/25	2.30M	4.00			-	KDC	
576			32.90	BURST			137°	4.30				-	ME	
GSP		2.5	32.90	BURST			133°					-	ME	
GSP		3.7	16.50	REMITA			133°					-	ME	

REMARKS BACK AZIMUTH 202°

COPY WITH REF. BY 112

PHOTO LOADING CHART

STATION 830.0/ 80-36 / 5748 EVENT YUGA DATE 3-11-58

FILM			CAMERA			LENS			EXPOSURE		REMARKS	
TYPE	EMULS. NO.	SIZE	MOLDER	PERF. NO.	NO.	PACK FOR.	FORM NO.	FOC. MM.	FILTER	APER		SHUTTER SPEED
M.F.	1112-9-2	70-106	IR-MAG	50681	705TR	B-2	40/500	154	ND-5	f8	-	3X10 ¹⁰
				50679	705TR	B-1			R-1-4	f8	-	3X10 ⁹
				50680	705TR	C-1			ND-3	f8	-	3X10 ⁸
				50681	35FF	C-2	2000	102	ND-2	f8	-	1X10 ⁶
				50682	M-1	B-4	24	35	W-12	f20	30°	2X10 ⁴
				50683	M-70	B-1	373	80	W-12	f4	1/500	f0
				50684	C-70	A-1	1/4	105	W-12	f5.6	1/25	f0
				50685	G-5P	B-1	64	12.5	-	f5.6	1/33	f0
				50686	G-5P	B-2		2.5	W-12	f2		f0
				50687	G-5P	B-1		3.7	-	f4.5		2X10 ²

DATE FILM LOADED 27-2-58 DATE CAMERA LOADED DATE EXPOSED

REMARKS

COPY OF ORIGINAL

COPY OF ORIGINAL

SECRET

STATION NO. 81002 EVENT. JULLA
 STATION TYPE BB-36 BRG 96°00' GZ STA. 42
 DISTANCE GZ 10.7 NM STATION' DIFF. TILT DATE 2-19-58
N 49° 14' 6.7 6.02 3.24° 96° POSTED
 DISTANCE OBJECT 13.666' E 277.222 GZ 0.702
Z 37.000 1.27 4.7680

CAMERA NO.	FROM BACK POS.	POC. MM	LENS		FIELD TARGET H/V	OBJECT	AIMING		POWER			MARKER TYPE	S/M	DELAY	FILM	PUR. POSE	REMARKS
			S/N	F/T/R			H	V	VOLTS	SHUT SMO.	TIME ON/OW						
20518	30%	C-1	152	2214514	ND-5	31.370	BLAST	0.00	114.0	210	-	2.5	262	23	MF	8.3	
20518		D-1		1975405	ND-4												
20518		D-2		501660	ND-3												
35EE	2.000	C-2	102	81288	W-12	12.87			120DC								
M-2	2.4	B-4	35	1158110	W-12	21.39			210DC	30°	1.5	1.5	225	23			
M-70	3/4	B-1	80	100357		56.55				1/200	1/100				FX		
5-70	1/4	A-1	105	88201		43.03				1/25	1/100				MF		
G-5P	64	B-3	18	11495		46.76				133°	1/200				KDC		
G-5P		B-2	25	42117	W-12	32.90	ARC			133°	1/200				MF		
G-5P		UPPER	37	205		165°	ZENITH	-90°		133°					MF		

REMARKS BACK AZIMUTH 276°

SOFT WITH REV. 8.1.50

STATION 81062 08-16-1570						EVENT 1258			DATE 2-11-58	REMARKS				
TYPE	EXPL. NO.	SIZE	HOLDER	PART. NO.	CAMERA			LENS		EXPOSURE				
					NO.	MACK POS.	MON. SPD.	FOG MM	FILTER	APER	SHUTTER SPEED	W/M ²		
MF	112-7-2	20-120	V-ANG	50700	C-1	20	1/25	152	NO. 5	f8	--	2x10 ¹⁰		
				50699	D-1				NO. 7			2x10 ⁹		
				50701	D-2				NO. 3		--	3x10 ⁸		
	112-7-1	30-400	BALANCE	50702	C-2	2000	10.2	NO. 2	NO. 5			1x10 ⁹	0.070	
	112-7-7	30-200	M-ANG	50703	B-7	27	35	NO. 12	NO. 12	f20	30°	2x10 ¹¹	1.092	
FX	220-262	20-50	M-ANG	50704	B-1	3 1/2	80			f4	1/500	40		
MF	112-7-3	70-100	M-ANG	50705	A-1	1/4	105			f56	1/25	40		
MDC	26136	6-50	V-ANG	50706	B-3	04	185		--		133°	40		
MF	112-7-05			50707	B-2		25	NO. 12		f2		40	0.071	
				50708	B-2		37			f43		2x10 ¹¹	8.772	
DATE FILM LOADED 7-23-58						DATE CAMERA LOT 1			DATE EXPOSED					
REMARKS														

copy of original

STATION NO. 943-1155 BOXER BRG U.S.C.A
 STATION TYPE SHLE STATION G. DIFF. 2-12-58
 DISTANCE GZ N TILT 2-12-58
 DISTANCE OBJECT E GZ ORU POSTED

PHOTO PLAN

CAMERA NO.	NON SPD.	BACK POS.	LENS		FIELD TARGET H/V	AIMING		POWER			MARKER		DELAY	FILM	PUR. POS.	REMARKS
			FOC. NUM.	S/N		OBJECT	H	V	VOLTS	SHUT BRNG.	TIME CM/OP.	TYPE				
#3	1/4	1	152	41224	N-12	0-20	0-20	1580	1/2	2-3/2	-	-	-	ME	83	
#1	20/4	2	304	58605	N-12	0-20	0-20	1400	-	2-3/2	-	-	-	ME		
#2	1/2	3	40	RE-15	-	0-20	0-20	1330	133	5-1/2	-	-	-	KIX-0		
#4	64	4	37	144	N-12	165°	ZENITH			2-3/2	-	-	-	ME		

REMARKS

COPY OF ORIGINAL

PHOTO LOADING CHART

STATION 943 USS BELA EVENT YUSLA DATE 3-11-58

TYPE	FILM			PERF. NO.	CAMERA		LENS		EXPOSURE		REMARKS	
	EMULS. NO.	SIZE	HOLDER		MAX. PPS	MON. SPD	FOG MM	FILTER	APER	SHUTTER RMCO		W/M ²
ME	1112-9-2	702-102	500L	50870	1	1/4	1.5A	V-12	f5.6	1/4"	.50	
ME		"-100	STR MAG	50871	2	10/	3.0A	M.D. 2	f7		2.2x10 ⁻⁷	
KOC	263368	11-50	U-MAG	50872	3	32	4.0	-	f8	115°	.50	
ME	712-07-05	11-50	U-MAG	50873	4	64	3.7	V-12	f4.5	133°	.50	

DATE FILM LOADED 46-25-CR DATE CAMERA LOADED 11
 REMARKS _____

COPY OF ORIGINAL

COPY OF ORIGINAL

Appendix C
PHOTO DATA SHOT TEAK

STATION NO. 830 01 EVENT LEAK
 STATION TYPE RR-26 1575E BRG 537.2 GZ STA. HIGH ALTITUDE
 DISTANCE OZ N 5.5 1.6 8 STATION GZ DIFF. TILT 27.1 20 DATE 7-21-58
 DISTANCE OBJECT Z 3.0 3.0 0 GZ 1.9 4.2 1 ONJ 17.6 4.1 9 POSTED 219874

PHOTO PLAN

CAMERA	LENSE	FIELD TARGET	AIMING			POWER			MARKER	OBLAY	MAG	PUR. POSE	REMARKS
			OBJECT	H	V	YOLTS	SPRT. BRHO.	TIME ON/OFF					
DESTA 10	C-1 153	195098 ND-11	RURST	200	1.5	2800							
20-370	D-1	162745 ND-3											
22-310	D-3	72048 ND-11											
17-1	2000	102 B 13878 V-12				1400							
17-2	34	35 3448071				2400	170	13.6	2.5				
17-3	3 1/2	80 4892032				1500	150						TX
17-4	1/4	105 RM 119				1500	150						TX
GSP 174	64	185 11257				133	130						KDC
GSP 174	B-3	2.5 22718 W-12				133	130						TX
GSP 174	E-1	345 147				165	2600						MF

REMARKS THE CAMERA IS IN ON TIME AND RE TO BURST TIME

COPY OF ORIGINAL

COPY OF ORIGINAL

		STATION <u>830 01 8036-15742</u> EVENT <u>LEAK</u>								DATE <u>7-25-58</u>				
TYPE	EMULS. NO.	SIZE	FILM				LENS				EXPOSURE		REMARKS	
			MOULDER	PERF. NO.	NO.	BACK POS.	HOVA SPC.	FOG MM	FILTER	APER	SHUTTER RHEO.	W/M ²		
MF	112-9-2	7-100	SUR-MAG	54157	20-SIB	C-1	45	152		NR-1	f 16	---	10 ³	
				54148	20-SIB	E-1				ND-3	f 6.3	---	10 ⁵	
				54148	20-SIB	D-2				ND-1	f 6.3	---	10 ⁴	
	112-7-1	135-300	MINI-MAG	54150	25-FF	C-2	2000	102		W-12	f 8	---	10 ⁴	
	112-7-3	25-300	MAG	54151	M-1	B-4	24	35			f 2.8	170 ⁰	20	
IX	328-5	10-50	MINI-MAG	54152	M-70	B-1	3 1/2	80			f 4	1/500	8	
IX	336-4	70-100	MAG	54153	65-70	A-1	1/4	105			f 4.5	1/25	0.1	
KOC	204-005	10-50	MINI-MAG	54154	65-P	B-3	64	125			f 2.8	133 ⁰	15	
IX	328-11			54155	65-P	B-2		35		W-12	f 2.8	133 ⁰	1	
MF	112-8-01	7		54150	65-P	E-1		2.45			f 2.8	133 ⁰	100	

DATE FILM LOADED _____ DATE CAMERA LOADED _____ DATE EXPOSED _____

REMARKS _____

COPY OF ORIGINAL _____

STATION NO. 830.02 EVENT I.E.A.K.
 STATION TYPE B.B.36-15750 BRG 202.327 GZ STA. HIGH ALTITUDE
 DISTANCE GZ N 55126.9 STATION 1 Z DIFF. TILT DATE 7-21-52
E 37227.8 194871 182407 ORJ POSTED
 DISTANCE OBJECT Z 30500 250374 219874

CAMERA	LENS		AIRING		POWER		MARKER		DELAY	FLA	FIR. POSS	REMARKS
	MOON SFD.	POC. MM	OBJECT	V	VOLTS	INIT. RHO.	TRM ON/OFF	TYPE				
70 STA 505	C-1	152	BURST	0-00	28DC	-	-20	300	23	-	MF	8.3
70 STA 206	D-1	172					-20			-		
70 STA 207	D-2	172					-20			-		
55 F13050	C-2	192			120DC		-20			-		
M 207	B-4	35			240DC	170	1/20	175	23	-		
M 207	B-1	80	CLOUD				1/20			-	TX	
M 207	B-1	105					1/20			-	TX	
M 207	B-3	185	DRS				1/20			-	KDC	
M 207	B-2	25	BURST				1/20			-	TA	
M 207	E-1	345	ZENITH	90			1/20			-	MF	

REMARKS: CAMERA EXPOSURE TIMES ARE RELATIVE TO GZ TIME

PHOTO LOG DING CHART

STATION 6-02 10-5-5720 DATE 7-25-57

EVENT 11-2

TYPE	EMULS. NO.	SIZE	HOLDER	PERF. NO.	NO.	RACK POS.	NO.1 SPD.	LENS		EXPOSURE		REMARKS
								FOC. MM.	FILTER	APER	SHUTTER RE-FO.	
MF	112-7-3	71-100	STRANA	54137	70 STR	C-1	45'	154	ND-2	f 16.0	-	8
			M56	54137	#5					f 6.3	-	6
				54131	10 STR	D			ND-3	f 6.3	-	10
				54139	70 STR	B-2			ND-1	f 6.3	-	10
			RAYLOUT	54129	#2				W-12	f 6	-	10
	112-7-1	35-400	STRANA	54129	2-FF	C-2	2000	103		f 2.8	170	20
			MISC WALL	54121	M #2	F-4	2.4	35		f 4	200	8
	112-7-3	31-200	MAG	54121	M #2	B-1	3 1/3	80		f 4.5	125	0.1
IX	52-73	21-50	MAG	54122	M #2	B-1	3 1/3	80		f 4.5	125	0.1
IX	336-5	21-50	MAG	54122	M #2	B-1	3 1/3	80		f 4.5	125	0.1
IX	336-5	21-50	MAG	54122	M #2	B-1	3 1/3	80		f 4.5	125	0.1
KDC	52-73	21-50	MAG	54122	M #2	B-1	3 1/3	80		f 4.5	125	0.1
IX	336-5	21-50	MAG	54122	M #2	B-1	3 1/3	80		f 4.5	125	0.1
MF	112-8-02			54143	GSP	B-2		25	W-12	f 2.8	133	15
				54143	GSP	B-2		25	W-12	f 2.8	133	15
				54146	GSP	E		3.45		f 2.8	133	100

DATE FILM LOADED _____ DATE CAMERA LOADED _____ DATE EXPOSED _____

REMARKS _____

COPY OF ORIGINAL

STATION I O. 831 6x6 7

STATION TYPE I. BUCK

DISTANCE GZ N 200450

DISTANCE OBJECT E 200530

PHOTO PLAN

STATION 07

DIFF. 2694

N 1.1

E 195871

BRG 295 22 24

TILT 08 34

GZ 08 34

EVENT TEAK

GZ STA. HIGH ALTITUDE

DATE 7-21-58

POSTED

OBJ 250374

250370

CAMERA	LENS		FIELD TARGET H/V	AIMING		POWER		MARKER TYPE S/N	DELAY	FRM	PUR-POSE	REMARKS
	NO. S/P	POC. AIM		OBJCT	H	V	VOLTS					
DESTA 30/7	C-1	304	45	0.00	82.15	210C	-	2 1/2	-	ME	8.3	ACTUAL DELAY 29 0 11
XB-2 7.11	A-2	430	35			157AC BULB			25.00	EX		ACTUAL DELAY 52 5 00
XB-2 5.22	A-3	480	35			155AC BULB			50.00	EX		
SEF 2.00	C-2	150	35			130DC			-	ME		
H-70 1.1	B-1	150	35			155AC 1/25			-	EX		
H-70 1.4	A-1	30	50			155AC 1/75			-	TX		
G-5F 6.4	A-1a	40	60			248C 133			-	KDC ECT		
35FF 2.00	C-2	150	35			120AC			-	1229	18.1	
F-16 6.00	E-1	53	375			180AC			-	ME		GOOSE UNIT
F-16 5.00	D-1	53	375			180AC			-	ME		GOOSE UNIT
G.S.P. 6.4	TRUCK	345	165			2+DC 133			-	ME	8.3	

REMARKS ALL TURN ON TIMES ARE RELATIVE TO: TIME

COPY OF ORIGINAL

COPY OF ORIGINAL

SECRET

PHOTO LOGGING CHART

STATION 831 6 A 6 P EVENT LEAK DATE 7-24-58

TYPE	FILM		PERF. NO.	C. I. R.	LENS			EXPOSURE		REMARKS		
	EMULS. NO.	SIZE			HOLDER	NO.	RACK POS.	NOM. SPD.	FOC. LEN.		FILTER	APER
MF	112-7-2 6140	70-100	STR-MAG	54126	20-STR	C-1	152	304	ND-5	f6.8	-	5 x 10 ⁷
FX	112 E10	74 x 3 1/4	HOLDER	54127	AR-7	A-2	152	480	-	f11.0	BULB	2 x 10 ⁷
FX				54128	XR-8	A-3	152	480	-	f11.0	1:1.0	2 x 10 ⁷
MF	112-7-1 5240	35-400	SPool	54124	35 F.F.	C-2	2000	152	W-12	f8.0	-	10 ⁴
FX	626-2	70-100		54130	H-70	B-1	375	152	W-12	f5.6	1/75	3
TX	236-4	70-100		54131	H-70	A-1	1/4	38	W-12	f4.5	1/75	0.1
KDC	244605 1339	16-50	W-MAG	54132	G-3P	A-1	54	40	-	f2.8	1/33	15
1339	322-1	35-500	SPool	54133	35 F.F.	C-3	2000	152	ND-4	f16.0	-	2 x 10 ⁵
MF	112-8-22	14-100	H.S. REEL	54134	F-16	E-1	6000	5.3	-	f8.0	-	2.5 x 10 ⁵
TRIX		16-100	H.S. REEL	54135	F-16	E-1	6000	5.3	ND-3	f8.0	-	2.5 x 10 ⁵
MF	112-8-02	16-50	W-MAG	54126	G-3P	TAVER	64	345	-	f2.8	1/33	100

DATE FILM LOADED _____ DATE CAMERA LOADED _____ DATE EXPOSED _____

REMARKS 5 x 10⁷ W/M² NOMINAL FOR ALL CAMERAS

SOFT PL ORIGINAL

Appendix D
PHOTO DATA, SHOT ORANGE

STATION NO. 93001 EVENT PHASE
 STATION TYPE 213 BRG 120° 12' GZ STA. 1164
 DISTANCE GZ: N 4.12 15' DIFF. 0 TILT 14° 30' DATE 14 11 58
 DISTANCE OBJECT: E 30.5 10' GZ 114 30' OBJ 114 30' POSTED

PHOTO PLAN

CAMERA		LENS		FIELD TARGET		AIMING		POWER			MARKER		DELAY	FILM	PURPOSE	REMARKS	
NO.	MOI. SPD.	BACK POS.	FOC. MM.	S/M	FILTER	H/V	OBJECT	H	V	VOLTS	SHUT RHEO.	TIME ON/OFF	TYPE	S/N			
207	100	C-4	152	95090	N/D-Y	103	130NSI	0°00'	120°	25VDC	-	2.2	200	24		MF	BS
208		B-1		20-9456	N/D-3	105											
209		B-2		720988	110-1	105											
300	3000	C-2	102	312928	11-12	102				120DC							
401	24	B-3	35	1278077		309				240C	1700	1.2M	12 1/2	25			
402	33	B-1	81	949032		312	LOUD				1.20	1.1M				TX	
403	14	A-1	105	RW109		317					1.5	1.5M					
404	14	B-3	183	11243		253	DOC				1.50	1.50				KUC	
405		B-2	25	231026	11-12	151	BURST										
406		B-1	375	115		105	20000		90°							MF	

REMARKS: CORRECTION IN TIMES ARE RELATIVE TO RECORDER'S ADJUST TIME

COPY OF ORIGINAL

STATION		EVENT		DATE		DATE		REMARKS					
830 01 20 16		15748		1948		8-2-58							
FILM				CAMERA				LENS		EXPOSURE		REMARKS	
TYPE	EMULS. NO.	SIZE	HOLDER	PERF. NO.	NO.	FRONT POS.	NO. OF EXPOS.	FUC. DIA.	FLYER	APER.	SHUTTER SPEED.		W/M ²
MF	1-9-1	73-100	57301	57301	20	15'	15'	15'	110-7	f 16		1.08	
			57301	57301	20	15'	15'	15'	110-3	f 6.3		1.06	
			57302	57302	20	15'	15'	15'	110-1			1.07	
			57303	57303	20	15'	15'	15'	110-12	f 8.0		1.07	
			57304	57304	20	15'	15'	15'	110-1	f 2.8	1.25	2.0	
			57305	57305	20	15'	15'	15'	110-1	f 4.0	1.20	8	
			57306	57306	20	15'	15'	15'	110-1	f 4.5	1.35	0.1	
			57307	57307	20	15'	15'	15'	110-1	f 2.8	1.30	3'	
			57308	57308	20	15'	15'	15'	110-12			1	
			57309	57309	20	15'	15'	15'	110-1			1.00	

DATE FILM LOADED _____ DATE CAMERA LOADED _____ DATE EXPOSED _____

REMARKS _____

SECRET

1024 of 156486

STATION NO. 93002 EVENT 1000
 STATION TYPE 2030 13 230 BRG 200000 GZ STA. 1000 000
 DISTANCE GZ 10000 STATION G7 DIFF. 100000 TILT 0
 DISTANCE OBJECT 10000 E 100000 GZ 100000 DATE 10 10 50
 Z 100000 POSTED 100000

PHOTO PLAN

CAMERA NO.	MOV. SPD.	BACK POL.	FOC. MM.	LENS		FIELD TARGET H/V	AIMING			POWER			MARKER TYPE	S/N	DELAY	FILM	PUR. POSE	REMARKS	
				S/N	FILTER		OBJECT	H	V	VOLTS	SHUT R/NO.	TIME ON/OFF							
10310	100	1-1	152	211734	10-7	123	1000	0.2	200	200	100	100	200	23		MF	B3		
10310	100	0-1		197440	10-3														
10310	100	0-2		50560	10-1														
10310	2000	C-2	107	81288	10-12	102			1000										
10310	200	0-1	35	95806		103			200				122	22					
10310	3 1/3	B-1	80	50033		104			100										
10310	14	A-1	105	40020		105			100										
10310	64	B-1	185	11485		106			100										
10310	12	B-2	25	40301	10-12	107			100										
10310	10	E-1	30			108			100										

REMARKS: 100000 1000 000 1000 000 1000 000

STATION 81002 RA-36 51230 EVENT 0RRR05 DATE 8-2-58												
FILM				CAMERA			LENS		EXPOSURE		REMARKS	
EMULS. NO.	SIZE	HOLDER	REF. NO.	NO.	RACK FOR	NO. SLD	FOG	FILTER	APERT.	SHUTTER SPEED		W/M ²
MF	1112 9.1	70-100	Spass	54250	201EP	1	20%	15	N0-5	f16		106
				54251	201EP	2			N0-3	f6.3		106
				54292	201EP	1			N0-1			104
	1112 7-1	35-7500	201E	54293	15-20	2	2000	102	M-12	f80		103
	1112 7-2	35-2000	201E	54294	M-2	3	24	35		f2.8		20
TX	3443	70-150	MA9C	54295	07	1		80		f40		8
		70 100	B-073	54296	M-20	3	1/4	105	1	f45		01
			MATER.	54297	05	1		185		f2.8		15
KDC	204605	..50	U-MINE	54298	B-3	2	64	25				1
TX	3473			54299	B-2	1		345	M-12			00
MF	1112 8-2			54299	M-1	1						00
DATE FILM LOADED				DATE CAMERA LOX				DATE EXPOSED				
REMARKS												

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STATION NO. 73 **PHOTO PLAN** BRG 11221 EVENT 24 40
 STATION TYPE 111 STATION G. DIFF. 11221 GZ STA. 11221
 DISTANCE GZ N 200000 DISTANCE OBJECT E 30000 GZ DATE 11 22 1950
 DISTANCE OBJECT Z 6 TILT 11221 OBJ. POSTED 11 22 1950

CAMERA NO.	NO. BACK POS.	FOC. AM	LENS		FIELD TARGET H/V	AIMING		POWER			MARKER		DELAY	FILM	PUR. POSE	REMARKS
			S/M	FILTER		OBJECT	H	V	VOLTS	SHUT RHO	TIME ON/OFF	TYPE				
111	1	304	SPG 18	NO 3	25	BURST	0.00	0.00	25 DC			1		MF	S 3	
111	2	480	77053		15				115 DC	3000		3	2.25	FX		
111	3	450	71352		17				2500	3000		3	3.00	FX		
111	4	150	34925	14	20				12000			1		MF		
111	5	150	2703-28		20	CLOUD			115 DC	15				FX		
111	6	158	34092	1	250					15				FX		
111	7	40	BM 11		250					15				FX		
111	8	50	BM 11		250	COC			240	350				FX		
111	9	50	45057	10	20	BURST			2000					FX		
111	10	5.3	C3-18		210				110 AC					MF		
111	11	5.3	C3-18	NO	200									FX		
111	12	3.25	3.25		1050	BURST			2700	330				MF	S 3	

REMARKS

STATION 031			EVENT 020000			DATE 0-2-58								
FILM				CAMERA				LENS			EXPOSURE			REMARKS
TYPE	EM/AS. NO.	SIZE	HOLDER	PERF. NO.	NO.	BACK FOCUS	NOM. SHUTTER SPEED	FOC. INCH	FILTER	APER	SHUTTER RECD.	W/M?		
A11	1112 9-1	2-100	SPC	54289	47		1/100	304	ND-3	f6.3				
A11	1100	2-100	KMP	54280	48	A-2	1/100	750		f11	BucB			
A11	1112 9-1	2-100	MAG	54281	48	A-2	1/100	450		f11	BucB			
A11	1112 9-1	2-100	MAG	54282	48	A-2	1/100	500		f8				
A11	1112 9-1	2-100	MAG	54283	48	A-2	1/100	500		f5.6				
A11	1112 9-1	2-100	MAG	54284	48	A-2	1/100	38		f4.5				
A11	1112 9-1	2-100	MAG	54285	48	A-2	1/100	110		f2.8				
A11	1112 9-1	2-100	MAG	54286	48	A-2	1/100	150		f16				
A11	1112 9-1	2-100	MAG	54287	48	A-2	1/100	500		f8				
A11	1112 9-1	2-100	MAG	54288	48	A-2	1/100	500		f8				
A11	1112 9-1	2-100	MAG	54289	48	A-2	1/100	500		f2.8				

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21

 DATE FILM LOADED _____ DATE CAMERA LOADED _____
 REMARKS _____

DATE EXPOSED _____

1112 9-1 020000

1112 9-1 020000

REFERENCES

1. "Technical Summary of Military Effects, Program- 19 (U)", Operation Teapot, WT-1153, February 1960, Office of the Chief of Staff for Weapons Effects Tests, Headquarters Field Command, Defense Atomic Support Agency, Sandia Base, Albuquerque, New Mexico. Secret Restricted Data.
2. F. H. Shelton, "Phenomenology of a High-Altitude Atomic Explosion", SC-3363 (TR), April 1954, Sandia Corporation, Albuquerque, New Mexico, Secret Restricted Data.
3. Rocket Panel Atmosphere, Physical Review, 1952 Vol 75, Page 1027.
4. Glenn P. Elliott and others, "Operation of Missile Carrier for Very-High-Altitude Nuclear Detonations (U)", Project 93a, Operation Hardtack, WT-1657, May 1959, U.S. Army Ballistic Missile Agency, Redstone Arsenal, Alabama, Secret Restricted Data.
5. J.C. Champeny, "Very Long Range Light Measurements", Contract AF 33(600)-36426, Report B-1863, Egerton Gerneshausen & Grier, Inc., Boston, Massachusetts, Secret Restricted Data.

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28 May 1996

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SUBJECT: Declassification of AD-360632L (WT-1649).

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for
Arduin L. Jarrett
ARDITH JARRETT
Chief, Technical Support

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