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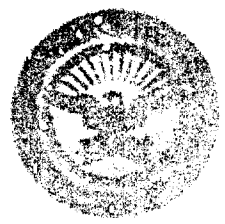
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# Operation CASTLE

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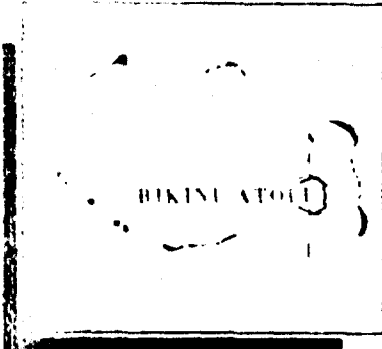
Project 1.1c

BASE SURGE MEASUREMENTS BY PHOTOGRAPHY

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**OPERATION CASTLE**

Agency AB  
Director  
Defense Atomic Support Agency  
Washington, D. C. 20301

Project 1.1c

**BASE SURGE MEASUREMENTS  
BY PHOTOGRAPHY**

*Report to The Scientific Director*

by

Richard L. Willey

George A. Young

C. J. Aronson

NOLR No. 1199

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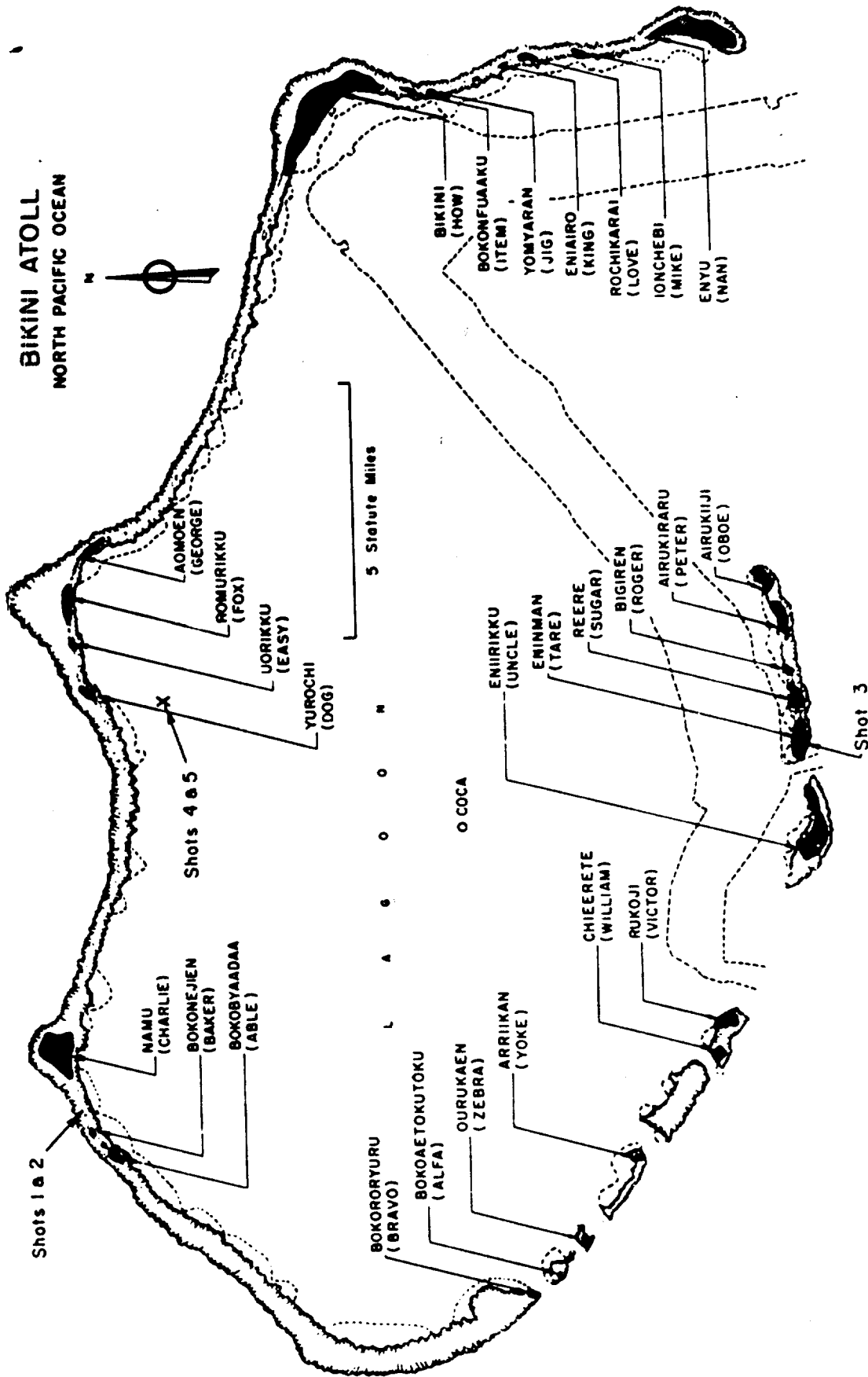
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**BIKINI ATOLL**  
NORTH PACIFIC OCEAN



GENERAL SHOT INFORMATION

	Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6
DATE	1 March	27 March	7 April	26 April	5 May	14 May
CODE NAME (Unclassified)	Bravo	Romeo	Koon	Union	Yankee	Hector
TIME *	06:40	06:25	06:15	06:05	06:05	06:15
LOCATION	Bikini, West of Charlie (Namu) on Reef	Bikini, Shot 1 Crater	Bikini, Tare (Eninm n)	Bikini, on Barge at Intersection of Arcs with Radii of 6900' from Dog (Yurochi) and 3 Statute Miles from Fox (Aomoen)		Eniwetok, IVY Mike Crater, Flora (Elugelab)
TYPE	Land	Barge	Land	Barge	Barge	Barge
HOLMES & NARVER COORDINATES	N 170,617.17 E 76,163.98	N 170,635.05 E 75,950.46	N 100,154.50 E 109,799.00	N 161,698.83 E 116,800.27	N 161,424.43 E 116,688.15	N 147,750.00 E 67,790.00

\* APPROXIMATE

## ABSTRACT

The major objective of Project 1.1c was the study of base surge phenomena on the Operation CASTLE shots by means of photography. No pictures of base surges were obtained, but aerial photographs for other projects indicated that base surges might have formed at times when the illumination was inadequate for surface photography. This cannot be established with certainty. Radar scope photography proved to be useful for indicating the region of heavy fallout. Further studies of this type would be recommended only for tests conducted during daylight hours.

## FOREWORD

This report is one of the reports presenting the results of the 34 projects participating in the Military Effects Tests Program of Operation CASTLE, which included six test detonations. For readers interested in other pertinent test information, reference is made to WT-934, Summary Report of the Commander, Task Unit 13, Programs 1-9, Military Effects Program. This summary report includes the following information of possible general interest.

- a. An over-all description of each detonation, including yield, height of burst, ground zero location, time of detonation, ambient atmospheric conditions at detonation, etc., for the six shots.
- b. Discussion of all project results.
- c. A summary of each project, including objectives and results.
- d. A complete listing of all reports covering the Military Effects Tests Program.

## PREFACE

The study of the base surge phenomena on the Operation CASTLE shots was conducted as a calculated risk since the scheduled times of firing were before sunrise. The primary analytical tool, photography, was almost useless; but, because of the unique experimental geometry and yields, it was felt that a reasonable attempt should be made to detect the presence of a base surge. On the other hand, the effort originally scheduled for this project was reduced to a minimum when it was learned that no shots were to be fired in daylight.

## ACKNOWLEDGMENTS

Appreciation is expressed for the assistance granted this project by CAPT Neil E. Kingsley (CEC) USN, Deputy Commander, Task Unit 13; Lt Col Jack G. James, USAF, Director of Program 9; Edgerton, Germeshausen and Grier, Inc.; Lookout Mountain Laboratory; Lt Col Triantafellu, USAF, Strategic Air Command; and the crews and cameramen of the USAF who took the aerial photographs and radar scope pictures.

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## CHAPTER 1

### INTRODUCTION

#### 1.1 OBJECTIVES

The objectives of the project were to determine if base surges were formed by the Operation CASTLE shots; and, if so, to obtain quantitative data concerning their characteristics by means of photography and instrumentation. An attempt was to be made to formulate scaling laws that could be used to predict the base surge effects of surface detonations with yields different from those attained in the CASTLE program.

#### 1.2 MILITARY SIGNIFICANCE

The base surge is of military significance as a carrier of radioactive contamination only if it can transport contaminants beyond the region of fallout and the area of destruction by other causes. This would possibly not occur with surface bursts. However, Project 1.1c was concerned primarily with the dynamics of base surge formation, growth, and dissipation, and with the general problems of scaling and predicting these effects; and it was felt that considerable knowledge of large-scale base surge phenomena could be gained from a study of the CASTLE results.

#### 1.3 BACKGROUND AND THEORY

The U. S. Naval Ordnance Laboratory has been conducting an investigation of base surge phenomena since the fall of 1949, under Task NOL-152. During this period, experiments were performed with high explosive charges weighing from 0.1 gram to 45 tons fired under water. <sup>1,2</sup> In addition, photographic records of underground high explosive tests conducted by other agencies in various types of soil were obtained and analyzed. <sup>3,4,5,6</sup> Studies were made of the Operation CROSSROADS Shot Baker records <sup>7</sup> and measurements were obtained of the Operation JANGLE surface phenomena. <sup>8</sup> As a result

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of these studies, scaling laws were obtained which could be used for the prediction of column diameter and the extent of base surge growth from submerged atomic weapons in relatively shallow water and from underground bursts.

Underwater, underground, and water surface explosions form approximately vertical columns of water droplets or soil particles with entrained air and explosion gases. The columns are roughly cylindrical and are probably hollow. Usually the droplet or particle size and spacing are such that the entrained gases are carried downward and the entire column drops in the manner of a heavy fluid, or aerosol, which flows outward radially along the surface to form a base surge. With favorable firing and meteorological conditions, the surge may traverse an area about 70 times as large as the area covered by the column before its radial motion ceases. It will then be carried downwind and will affect a much greater area.

The Shot Baker base surge lifted the ambient air in the lagoon to its condensation level and clouds were formed above the surge. The surge and upper clouds merged and rainfall was observed from these for about one half hour after the test. A similar effect would probably accompany the formation of any large base surge in an area with high relative humidity and atmospheric instability.

In general, column diameters scale according to the cube root of the charge weight when charges are fired at the same scaled depth. Base surge extent increases with increasing charge depth to a scaled depth of about  $1.0 \text{ ft/lb}^{1/3}$  for underground explosions and to a scaled depth of at least  $1.0 \text{ ft/lb}^{1/3}$  for underwater explosions. 1,3/

When a high explosive charge is detonated on the surface of the water a base surge is formed. However, the predictions of the size of the CASTLE base surge phenomena, which were based on these results, were considered to be approximate, as the surge scaling relationships for this charge geometry are not well understood. It was known from JANGLE results that an atomic burst on the surface of dry ground would not form a base surge; but it was felt that the formation of a small, but highly contaminated, base surge by a burst on the water surface was probable. An island shot would represent an intermediate condition, but would possibly raise enough water into the air to cause base surge formation.

The role of the base surge as a contaminating agent is not fully understood, and it is not known whether the surge contains radioactive materials when it forms or whether these are transferred from the fallout to the surge at a later stage. In any case, there is evidence from Shot Baker in CROSSROADS and from the underground shot in JANGLE that significant amounts of contamination were carried by the base surges formed in those tests. 9/ The CROSSROADS surge extended beyond the fallout area in all directions but the JANGLE surge exceeded the fallout extent only in the upwind direction. The base surge formed in the British Montebello test was small and was swamped by the fallout. 10/

## CHAPTER 2

# EXPERIMENT DESIGN

### 2.1 PHOTOGRAPHY

The original plan was for extensive aerial and ground photography of the base surges and other low level surface phenomena formed by all of the CASTLE shots. Estimates of the sizes of the phenomena were made for photographic planning; and it was assumed that even if a base surge was not formed by a shot, the cloud phenomena that developed at low levels could be studied on the photographic records.

When this project was notified of the decision to conduct the tests before dawn, it reduced its camera coverage to a minimum and planned to participate only in tests in which the shots were to be fired at a time when the possibility of obtaining usable photographs existed.

Radar photography of the early stages was planned for Project 6.1, and the films showing the later development were requested by Task Unit 13 for possible use by Project 1.1c.

### 2.2 INSTRUMENTATION

The design and testing of instrumentation to obtain records of temperature, relative humidity, and particle and droplet sizes in the base surges as functions of time was started during the early stages of planning for CASTLE. It was planned to build 18 self-powered units for placement on the islands for use on Shots 1, 4, 5, 3, and Echo (canceled), as originally scheduled.

Meteorological and Bathythermograph data were requested from Projects 9.3 and 1.4 so that a study of the effects of atmospheric conditions and water temperature on base surge behavior could be made.

With the reduction in photographic coverage and the uncertain results expected from the remaining cameras, it was decided to eliminate the attempt to obtain data with instrumentation. It was felt that the interpretation of the records would be doubtful without adequate photographic coverage of the phenomena.

The possibility of using flares for illumination was considered and a feasibility test was conducted with a TNT charge, but the method was not put into operation because of its high cost and doubtful practicability.

## CHAPTER 3

# RESULTS

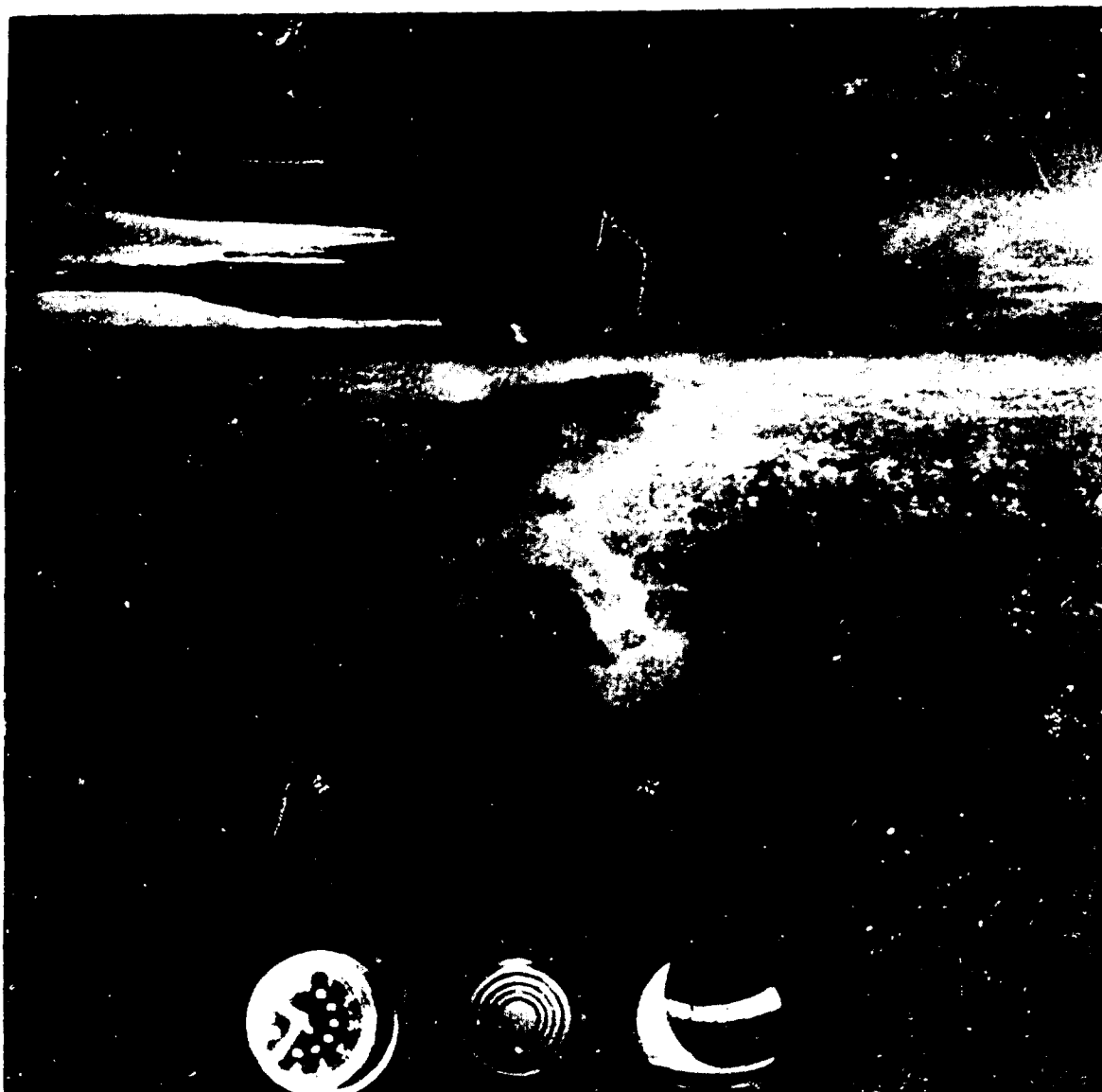
### 3.1 DIRECT PHOTOGRAPHY

The shot data pertinent to this report are summarized in Table 3.1 and on page 4 and the photographic coverage attempted primarily for Project 1.1c is listed in Table 3.2. No usable records were obtained, for the reasons indicated, but photographs made for other projects were available for study.

Films of Shots 1, 2, 4, 5, and 6, which were obtained for Projects 1.1a, b, and d and Project 1.2, were examined for evidence of base surge formation but proved to be unsuitable for this purpose. Satisfactory measurements of the early stages of development of the base stem could have been made in most cases but would have been of no significant value to this project. These films were exposed at rates of 24 and 100 frames per second for periods of less than one minute and pictures were obtained with the light of the fireball. However, when the fireball dimmed, the natural light at the surface of the ground was inadequate for photography at these speeds.

The aerial photography conducted for the purposes of Project 9.1 with K-17C cameras proved to be excellent for showing the late stages of cloud behavior on all shots except Shot 3, which was detonated on a day with heavy cloud cover and rain squalls. The Project 9.1 films which were examined are listed in Table 3.3.

A print selected from IML Film No. ALD-21 is presented in Fig. 3.1. This shows the fallout beneath the main Shot 2 cloud. An interesting feature was the large development of cumulus-type clouds on the edge of the fallout region. Eventually almost the entire lower cloud formation disappeared, except for the cumulus cloud development and part of a ring of cloud that may have encircled the entire fallout area at an earlier time. This late stage is illustrated in Fig. 3.2 (ALD-19) which shows the separation between the main upper cloud and the lower "stem" region.



ALTITUDE: 37,500 FT      DISTANCE FROM GROUND ZERO: 50 NAUTICAL MILES  
BEARING FROM GROUND ZERO: 191°

Fig. 3.1 Shot 2 Cloud, 21 min, 52 sec



ALTITUDE: 14,500 FT      DISTANCE FROM GROUND ZERO: 110 NAUTICAL MILES  
BEARING FROM GROUND ZERO: 237°

Fig. 3.2 Shot 2 Cloud, 29 min, 3 sec

TABLE 3.1 - Yields For All Shots

Shot	Yield (MT) Method
1	15 $\pm$ 0.5 Analytic Sol.
2	11 $\pm$ 0.5 Analytic Sol.
3	0.130 $\pm$ 0.020 Time Difference
4	7 $\pm$ 0.3 Analytic Sol.
5	13.5 $\pm$ 1.0 Analytic Sol.
6	1.7 $\pm$ 0.3 Analytic Sol.

TABLE 3.2 - Film Obtained for Project 1.1c

Shot	EG&G Film No.	Comments
4	24183	Film fogged by radiation
4	24184	Film fogged by radiation
6	24483	Camera tilted by air shock
6	24484	Camera tilted by air shock

For comparison, an aerial photo of the CROSSROADS Baker cloud phenomena at a relatively late stage of development is presented in Fig. 3.3 This shows the central region of fallout which developed from the cauliflower cloud and also shows "rainout" occurring from the base surge. The surge was capped by cumulus clouds which formed in the air it lifted to its condensation level. When the original surge and fallout had almost disappeared, the new cloud formation above the surge remained in the area.

The resemblance between the CROSSROADS Baker and CASTLE Shot 2 residual clouds indicated the possibility that a weak surge development occurred following Shot 2, forming after the waning of the fireball light and before good photographs of the surface were obtained.



ALTITUDE: 12,000 ft

TIME: 2 min, 41 sec

Fig. 3.3 Shot Baker Cloud Phenomena - Operation CROSSROADS

TABLE 3.3 - Project 9.1 Aerial Photographs Examined

Shot	IML Film No.	Shot	IML Film No.
1	ALD 9	4	ALD 31
1	ALD 10	4	ALD 33
1	ALD 11	4	ALD 34
1	ALD 12	5	ALD 35
2	ALD 18	5	ALD 36
2	ALD 19	5	ALD 37
2	ALD 20	5	ALD 41
2	ALD 21		

The lower clouds formed by Shot 1 resembled the Shot 2 clouds in appearance, as shown in Fig. 3.4. Usable photographs at analogous times were not available for the other CASTLE shots, though the main cloud phenomena at early times resembled the Shot 1 and Shot 2 clouds. The base stems from the barge and land shots exhibited differences in appearance due to differences in composition.

### 3.2 RADAR PHOTOGRAPHY

The photographic records from an airborne AN/APQ-24 radar scope were examined for Shots 1, 2, 3, 4, and 6 and compared with other photographs when possible. Although the echoes from the explosions could be readily detected in the radar photographs there was some doubt concerning the phenomena observed and it was felt that reliable quantitative cloud measurements could not be made from the CASTLE radar records. Attempts were made to correlate the radar observed phenomena with the photographic records made from other planes.

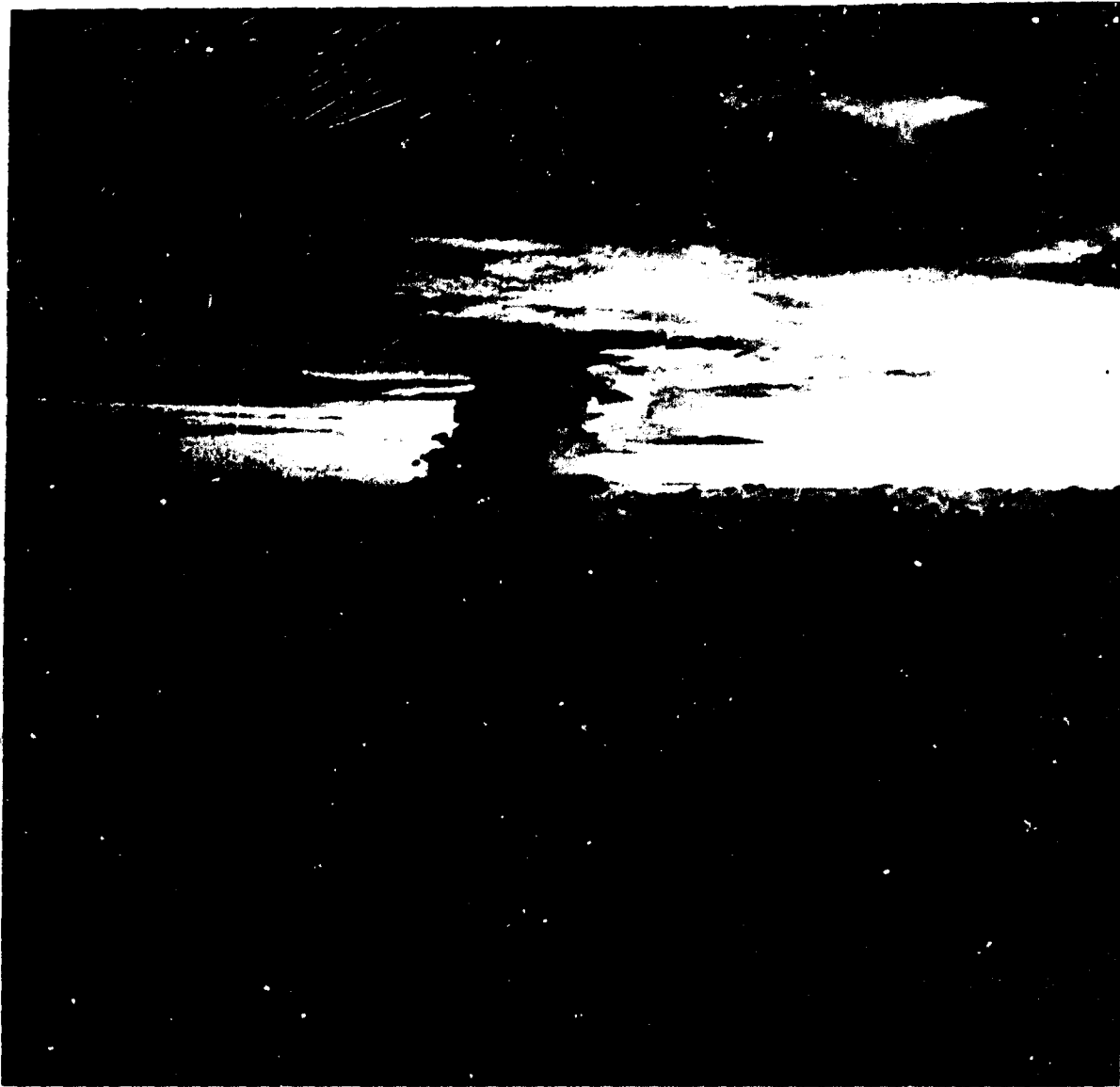
Figure 3.5 is a photograph of Shot 1 taken from an altitude of 14,000 ft at a distance of 74 nautical miles on a bearing of 207° from ground zero. Figure 3.6 shows the same shot from an altitude of 10,000 ft, 64 nautical miles from ground zero on a bearing of 310°. Figure 3.7a is a photograph of the airborne radar scope, altitude 29,900 ft, approximate bearing 127° from the Shot 1 ground zero. These three photographs were taken at approximately plus 20 minutes. The phenomena in the radar photographs and the direct photographs (Figs. 3.6 and 3.7), which were taken from bearings approximately 190° apart, showed some similarities.

In the measurement of the radar echo it was expected that the radar return would be strong from the region of heavy fallout, which would contain a relatively dense concentration of large water droplets. The heavy fallout was assumed to be the darkest portion of the echo, as indicated by the arrows, on Fig. 3.7b and was measured between these points. The measured value of 37,500 ft was in good agreement with the direct photograph measurement of 33,300 ft for the width of the main fallout region in Fig. 3.6.



ALTITUDE: 10,000 FT    DISTANCE FROM GROUND ZERO: 75 NAUTICAL MILES  
BEARING FROM GROUND ZERO: 275°

Fig. 3.4 Shot 1 Cloud, 32 min, 51 sec



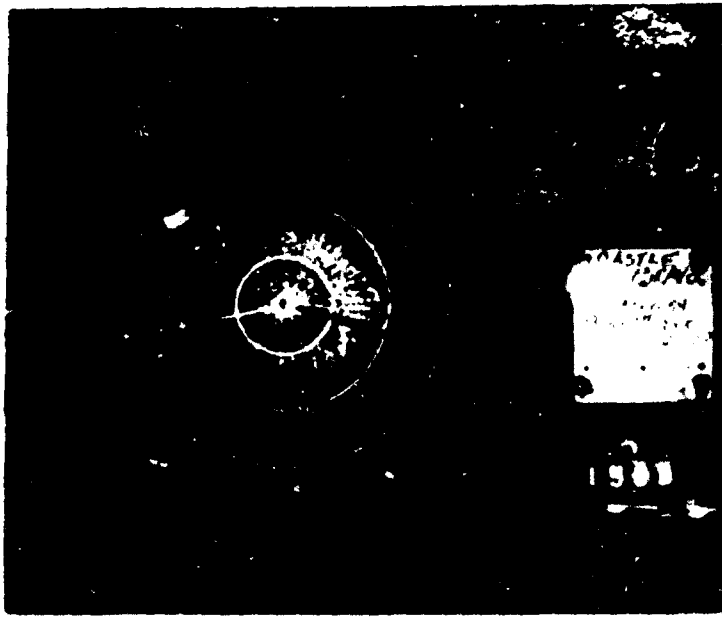
ALTITUDE 14,000 FT      DISTANCE FROM GROUND ZERO: 74 NAUTICAL MILES  
BEARING FROM GROUND ZERO: 207°

Fig. 3.5 Shot 1 Cloud, 19 min, 37 sec



ALTITUDE: 10,000 FT      DISTANCE FROM GROUND ZERO: 64 NAUTICAL MILES  
BEARING FROM GROUND ZERO: 310°

Fig. 3.6 Shot 1 Cloud, 19 min, 38 sec



A



B

Fig. 3.7 Shot 1 Radar Scope Photographs, 20 Min, 17 sec

In Fig. 3.7b, which is an enlargement of a portion of Fig. 3.7a, one of the two lobes was believed to be lateral cloud development, and the other possibly the area of heavy fallout on the water surface.

Figures 3.8 and 3.9 are photographic records of Shot 2 at approximately plus 15 minutes. The direct aerial photograph, (Fig. 3.8) was taken from an altitude of 37,500 ft, 50 nautical miles from ground zero, bearing 230°. The airborne radar photograph (Fig. 3.9) was taken at an altitude of 30,000 ft, bearing 93°. The Shot 2 radar pictures gave a measurement of 24,000 ft for the dense part of the echo and the direct photography (Fig. 3.8) gave a measurement of 21,700 ft for the diameter of the visible fallout. Because there were only a limited number of direct photographs, comparisons on other shots were not attempted.

Figures 3.10, 3.11, and 3.12 are photographs of the radar scope on Shots 3, 4, and 6, respectively. In most cases the echo received on the radar scope was "U" shaped. It should be noted for Shots 3 and 6 that the rain showers, which prevailed on the days of these tests, produced strong images on the scopes.

### 3.3 CONCLUSIONS AND RECOMMENDATIONS

A study of the surface photography obtained on CASTLE shortly after the burst, by the light of the fireball, and of the aerial photographs obtained at later stages when the natural light was adequate, indicated the possibility that a base surge had formed between the times these two types of photographs were made, at least for Shots 1 and 2. Since there was insufficient illumination during this period of interest, no actual records of base surge formation were obtained on CASTLE.

The radar coverage showed a strong return from the fallout of each shot, but was inadequate for a detailed quantitative study.

The limited material precluded a study of the effects of meteorological and oceanographic conditions on base surge phenomena.

The fallout instrumentation used in Projects 2.5 and 2.6 was, in general, not close enough to the bursts to obtain evidence concerning the existence of base surges.

No detailed study of base surge activity is possible without adequate light for photography. The use of land based weather radar and the employment of the techniques that have been developed for the study of weather phenomena would probably yield useful information concerning droplet size and liquid water content in the fallout and possibly in other parts of the clouds formed by nuclear detonations. This type of study would be most valuable if coordinated with conventional camera coverage.



ALTITUDE: 37,500 FT      DISTANCE FROM GROUND ZERO: 50 NAUTICAL MILES  
BEARING FROM GROUND ZERO: 230°

Fig. 3.8 Shot 2 Cloud, 15 min, 22 sec

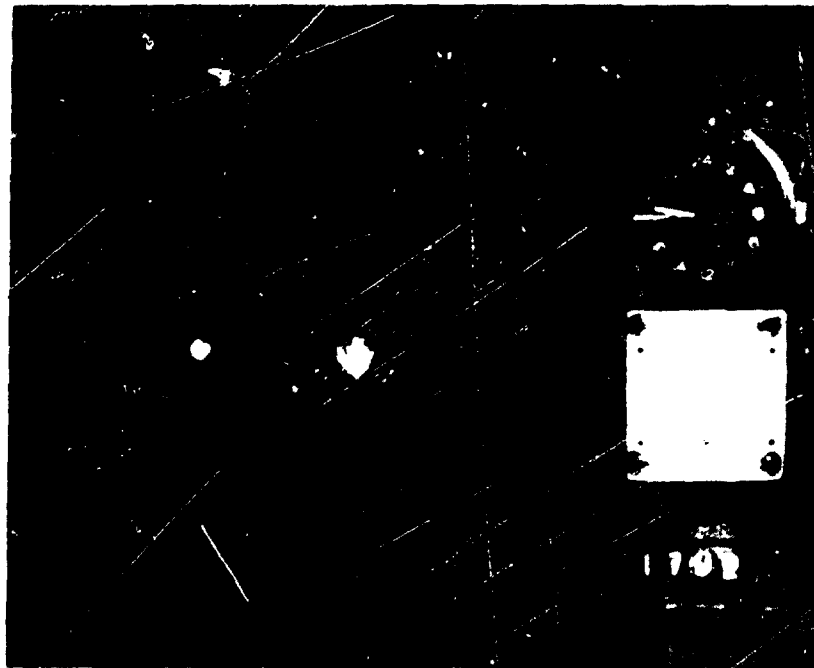
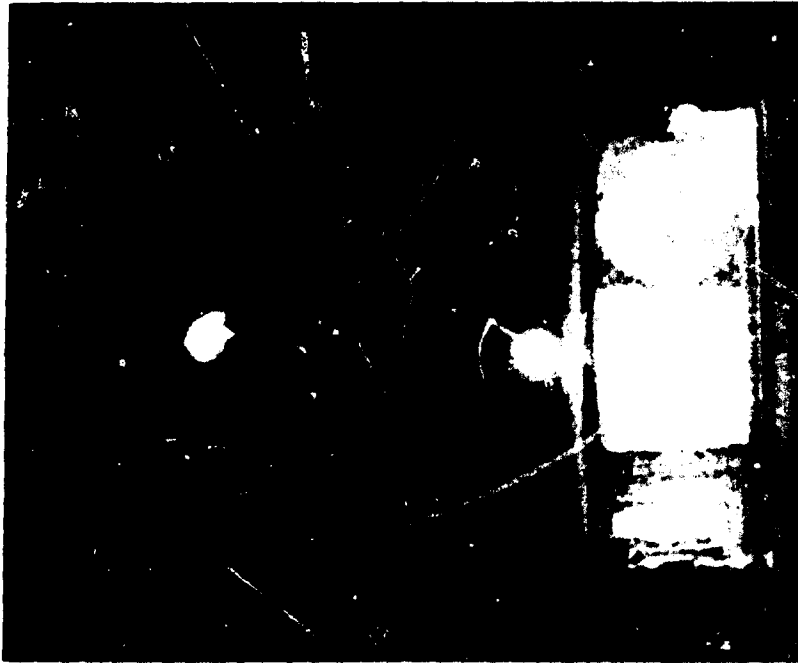


Fig. 3.9 Shot 2 Radar Scope Photograph, 15 min, 15 sec



Fig. 3.10 Shot 3 Radar Scope Photograph, 14 min, 13 sec



**Fig. 3.11 Shot 4 Radar Scope Photograph, 13 min, 18 sec**



**Fig. 3.12 Shot 6 Radar Scope Photograph, 16 min, 4 sec**

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