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JOINT TASK FORCE ONE
WASHINGTON, D. C.

In reply
Refer to:

18 Nov 1946

JTF-1/013
File: A16-3
Serial: 22

From: Commander Joint Task Force ONE.
To : The Joint Chiefs of Staff.

Subject: Technical Report of Operation Crossroads.

1. Submitted herewith is the technical report of Operation Crossroads, the atomic bomb tests conducted in July of this year at Bikini Atoll in the Marshall Islands.

2. This report is intended for the Joint Chiefs of Staff, such agencies of the War and Navy Departments as are entitled to receive it, the Joint Chiefs of Staff Evaluation Board, and of course the President's Evaluation Commission if they desire to see it.

3. This technical report is distinguished from the operational report which has been submitted separately. My own Summation of the Operation, including comments and recommendations, are contained in the operational report.

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W. H. P. BLANDY

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

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(6) **TECHNICAL REPORT**

of

OPERATION CROSSROADS [U] (8)

Prepared for Commander Joint Task Force One
for Transmittal to the Joint Chiefs of
Staff and their Evaluation Board

(10) [redacted] W. A. Shurcliff, [redacted] (11) 18 Nov 46, (12) 388p

Assisted by

Mr. D. Z. Beckler, Deputy Historian
Mr. Peregrine White, Assistant Historian
Mrs. Virginia Shapley, Editor
and others

(14) XRD-208

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PREFACE

This History, the Technical Report on Operation Crossroads, was begun on 29 Jan 46 at the request of Vice Admiral W. H. P. Blandy, Commander JTF-1. Preparation was guided principally by Rear Admiral W. S. Parsons, Deputy Commander for Technical Direction.

The History is based largely on Commander JTF-1 Operation Plan, No. 1-46, on the various administrative and technical histories, reports by the many groups within Joint Task Force One, and on material gathered from correspondence, interviews, and inspections. Care has been taken to locate authoritative sources for the facts presented. A file has been kept showing the sources of all significant facts. Since many of the data included are still in a non-final state, it is likely that a number of minor changes will be in order in the following months.

The History does not, of course, take the place of the detailed reports prepared by the various JTF-1 groups and identified in the Bibliography; it attempts mainly to combine in one unified work the salient parts of the many basic reports.

The History discusses failures as well as successes. A prominent research director has said "Every honest researcher I know admits he's just a professional amateur. He's doing whatever he's doing for the first time. That makes him an amateur. He has enough sense to know that he's going to have a lot of trouble, so that makes him a professional."

A "finder tab" system is included whereby the reader may turn instantly to any desired chapter on results.

To the many persons who helped in the preparation of this History I extend my thanks.

William A. Shurcliff

W. A. Shurcliff
Historian, JTF-1
18 Nov 46

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(A "Finder Tab" system is included to facilitate finding chapters on results.)

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SUMMARY

of

Technical Report of Operation Crossroads

Introduction.

The Joint Chiefs of Staff, acting with the approval of the President, created Joint Task Force One on 11 Jan 46 and charged it with determining the effects of atomic bombing on naval vessels. They directed that one bomb should be detonated in the air (Test A) and another underwater (Test B).

Evaluation groups were appointed; Congressional approval of use of naval vessels in the Tests was obtained; observers were named; the public manifested great interest in the preparations for the Tests.

Objects of the Tests.

In descending order of importance, the objects of the Tests were as follows:

- To determine the effects of atomic bombing on naval vessels, naval material, and ships' crews.
- To provide the Army Air Forces with experience in precision (atomic) bombing.
- To ascertain the effects of atomic bombing on a variety of army material.
- To show the kinds and extents of biological and chemical effects produced by radiations of all kinds.
- To discover successful means of diagnosing and treating persons exposed to radiations.
- To help answer a variety of hitherto-unanswered scientific questions in the fields of blast, meteorology, radioactivity, oceanography, seismography, radio propagation, and ionization.
- To determine the remote detectability of atomic bomb explosions.

Administration.

To carry out the assigned mission, Commander JTF-1 assembled from Army, Navy, and other agencies a staff, a technical organization, and a force organization capable of performing the required tasks. Technical activities were directed by R. Adm. W. S. Parsons, Deputy Task Force Commander for Technical Direction; air activities were directed by Maj. Gen. W. E. Kepner, Deputy Task Force Commander for Aviation. Maj. Gen. A. L. McAuliffe served as Ground Forces Adviser.

Commodore J. A. Snackenberg, Chief of Staff, was assisted by Capt. Robert Brodie (Navy), Assistant Chief of Staff for Personnel, Brig. Gen. (now Col.) T. J. Betts, Assistant Chief of Staff for Intelligence, Capt. C. H. Lyman (Navy), Assistant Chief of Staff for Operations, and Brig. Gen. (now Col.) D. H. Blakelock, Assistant Chief of Staff for Logistics.

Scientific instrumentation for evaluating the transient direct effects of the two explosions was the responsibility of Dr. R. A. Sawyer, Technical Director. His activities embraced these fields: bomb operation, pressure and impulse measurement, oceanography, electromagnetic propagation and electronics, radioactivity, optical radiation, nuclear radiation, remote measurements, and technical photography. For each of these fields a coordinator was designated. Detailed technical activities were carried out by ten administrative groups.

Determination of the effects of the explosions on the exposed vessels and other exposed material was the responsibility of R. Adm. T. A. Solberg, Director of Ship Material, who was responsible also for preparing the vessels and (after the second explosion) decontaminating them. Especially great care was given to inspecting the vessels before and after each explosion in order to determine the exact extent of damage, cause of damage and significance of damage. Activities were carried out by these eight groups: DSM Army Group, DSM Aeronautics Group, DSM Ships Group, DSM Ordnance Group, DSM Electronics Group, DSM Medical Group, DSM Supplies Group, DSM Yards and Docks Group.

Commander JTF-1 was assisted by a Safety Adviser (Capt. G. M. Lyon, Navy) and a Radiological Safety Adviser (Col. S. L. Warren).

The force organization comprised these eight groups: Technical Group, Target Vessel Group, Transport Group, Army Ground Group, Army Air Group, Navy Air Group, Surface Patrol Group, and Service Group.

The advance echelon was commanded by R. Adm. F. G. Fahrion; the rear echelon was directed by R. Adm. F. J. Lowry.

Technical Preparations.

Bikini Atoll was chosen as the site after it was found to satisfy adequately the nine principal criteria established. The Atoll's twenty six individual islands were given code names for convenience. Surveys were made, mines and coral heads removed, shore facilities constructed, moorings laid down, and natives removed to Rongerik Atoll.

Bombs of standard "Nagasaki" type, the most powerful type available, were used. Altitude and depth of the detonations were chosen after long consideration of all factors involved; achieving the greatest possible radius of serious damage was the principal criterion.

For Test A (detonation in air), the decision was made to drop the bomb from an airplane (B-29). A particularly expert crew was selected and very highly trained.

In Test B (underwater explosion) the bomb was suspended beneath an accurately moored vessel (LSM-60).

Elaborate plans were made for determining the amounts of energy released by the bombs.

Much thought was given to the choice and arrangement of target vessels. The principal desideratum was to obtain graded damage for all principal types and orientations of U. S. Naval vessels. No attempt was made to arrange the vessels so that the Tests would simulate use of the bombs against actual fleets at anchor or at sea; emphasis was placed, rather, on obtaining scientific and technical data which would serve as the basis for predicting what would happen in any of a great variety of tactical situations now or in the future. (The actual arrangements of the target vessels are shown in the tables and figures of Chaps. 10 and 20.)

Besides target vessels, a great variety of Army and Navy equipment was exposed. The equipment included ordnance, engineer, signal, medical, chemical, and quartermaster material; aircraft and landing ramps were exposed also.

Considerable numbers of pigs, goats, rats, mice, and guinea pigs were exposed on (or within) the target vessels to determine what symptoms resulted, how diagnoses might best be made, and what treatments were effective. Studies of fish and plant life were made also.

All test materials and animals were inspected carefully before and after each test; location and condition of each item were determined and recorded on special forms prepared in advance.

To determine pressure, optical radiation, nuclear radiation, etc., a great variety of standard and special instruments were prepared, tested, and installed. Some of these instruments were airborne, some were located beneath the surface of the water, some were located on shore towers, some were located on the technical support vessels; however, the majority were placed on the target vessels. Some were started by clocks; others were started by photocells or "black-box" radio-controlled instrument-starting devices. Cameras were used in great numbers.

Test A.

Bomb-A detonated 518 ft above the surface of Bikini Lagoon at 34 sec after 0900, 1 July 46, Bikini Local Time. It detonated 710 yd from the intended plan-view position. Seventy target vessels lay exposed, their positions being as shown in Chap. 10.

The amount of energy released was "normal" for an atomic bomb of the Nagasaki type; a total of 8.0×10^{20} ergs of energy was released, equivalent to the total amount of energy released in the exploding of 19.1 kilotons of TNT.

A total of 5 vessels sank as a result of the explosion; they were situated in the range: 50 to 760-yd horizontal distances from the projected Zeropoint. (Distances were measured to nearest point of vessel.)

Six (non-sunk) vessels were immobilized; they were situated at ranges of 560 to 920 yd.

Tanks and guns suffered no appreciable loss of military efficiency at ranges greater than 600 yd. Light vehicles and other light structures were severely damaged out to 1200 yd.

Electronic equipment and instruments were seriously damaged out to 1200 yd.

Packaged ammunition remained undamaged at ranges greater than 1000 yd.

Baled and packaged clothing was damaged, primarily by fires, up to 2000 yd; tires were undamaged (except for superficial scorching) at and beyond 600 yd; plastics were damaged at distances as great as 2000 yd.

Nonperishable packaged food at 500 yd was cleared for consumption by four days after A-Day.

More than 50 percent of the test animals situated within 1000 yd of the Zeropoint died; between 15 and 30 percent of the test animals in the annulus from 1000 to 2000 yd died; 5 to 15 percent of the test animals outside 2000 yd died.

Air blast (including primary and secondary effects) was the principal cause of injury leading to immediate "loss of military efficiency" of the test animals; however, many of the animals killed by the air blast received lethal dosages of gamma radiation.

Principal cause of delayed deaths was gamma radiation.

Values of peak pressure in air just above the Lagoon surface were: 2000, 53, 10.5, 4.8, and 3.1 psi gage at horizontal distances of 0. 500, 1000, 1500, 2000 yd from the projected Zeropoint. At 26,800-ft altitude and 11,500-yd slant range the peak pressure was 0.17 psi gage.

The duration of the positive pressure pulse was 0.46 sec and 0.75 sec at horizontal distances of 500 and 1000 yd, respectively.

The shock wave in air had an initial "slant range" velocity of over 14,000 ft/sec; at 1/2 mi slant range the wave had a velocity of approximately 1800 ft/sec.

Peak pressure in closed (surviving) vessels never exceeded 2.5 psi gage.

The directly determined value for total amount of energy emitted by the detonation as optical radiation (including ultraviolet, visible, and infrared light) in the spectral range from 3400 to 24,000 A was 1.7 X 10^{21} ergs, although this figure (corresponding to 40 kilotons of TNT) is obviously far too large. At 12 nautical miles the peak illumination was approximately 10 times greater than is produced by noon summer sun and skylight.

The fireball had a maximum surface temperature of roughly 200,000° K; the radius of the fireball was 110 ft at one millisecond after Mike Hour and 800 ft at one second after Mike Hour.

The great majority of the gamma radiation reaching target vessels reached them within the first 10 sec. Cumulative gamma radiation dosages at exposed locations at 600, 1000, 1500, and 2000 yd from the projected Zeropoint were 9000, 1800, 220, and 28 roentgens, respectively. The dosage at 1350 yd was approximately 400 roentgens (lethal).

Neutron dosages were not lethal at horizontal distances greater than 550 yd.

By 150 sec after Mike Hour the cloud had reached an altitude of nearly 5 mi; its maximum width was 9000 ft, and a thin cap, presumed by some to be an ice cap, had formed. By 400 sec after Mike Hour the cloud had reached 7 mi.

Radioactivity from the explosion was detected at many remote sites, including Continental U. S., several days later.

The following Table presents estimates by the JTF-1 Technical Historian as to the ranges at which specified loss of military efficiency during the first hour after Mike Hour is probable:

Extent of Immediate Loss of Military Efficiency	Range (yd)		
	Typical Ship	Typical Crew	Ship and Crew in Combination
Very Serious	900	700	900
Serious	1000	800	1020
Moderate	1300	900	1300
Slight	1500	1000	1500

Obviously, the weak link as regards immediate loss of military efficiency is the ship itself. If resistance of stacks and (antenna-supporting) masts could be appreciably increased, a reduction of roughly 100 yd could be effected in the range of immediate loss of combined military efficiency.

Shock wave in air is the cause of greatest immediate (i.e., first hour) loss of military efficiency of ships themselves. Shock wave in air would compete with optical radiation as the principal cause of immediate loss of military efficiency of crews per se which are situated outside 900 yd. In the annulus from 600 to 900 yd gamma radiation would be the principal cause of loss of military efficiency of crews per se; and within 600 yd neutron and gamma radiations compete as the principal cause. Radiation intensities at ranges less than 550 yd are of reduced interest since ships within 550 yd will ordinarily be sunk.

A typical surface combatant vessel will probably be sunk by a pressure wave in air having a peak pressure greater than 35 psi gage; it will probably suffer very serious immediate loss of military efficiency when subjected to a peak pressure greater than 25 psi gage; peak pressures of 20, 15, and 10 psi gage will probably produce serious, moderate, and slight immediate losses of military efficiency, respectively.

Peak pressures of 25 and 4 psi gage will probably produce (respectively) very serious and slight immediate losses of military efficiency of personnel.

The Operation had no important shortcomings; but these minor imperfections deserve mention: The bomb detonated 710 yd from the intended Zeropoint, for cause unknown; the timing signal relied on for starting a number of the instruments was sent out a few seconds late, as a result of two errors by the timing signal operator; a number of instrument-starting black boxes failed to operate satisfactorily, for a combination of reasons.

From the technical point of view as well as from the operational point of view the Test was very successful. Graded damage was produced in ships of many types; graded injury was produced in animals of several types; and the principal physical phenomena (causative factors) were evaluated with reasonably high accuracy. A firm basis was established for determining the vulnerability of ships and crews to air bursts of atomic bombs, and for improving future designs and tactics.

Test B

Bomb-B detonated 90 ft beneath the surface of Bikini Lagoon at 59.7 sec after 0834 on 25 July 46, Bikini Local Time. The positions of the target vessels are shown in Chap. 20.

The amount of energy released was "normal" for an atomic bomb of the Nagasaki type; a total of 8.5×10^{20} ergs of energy was released, which is equivalent to the total amount of energy released in the exploding of 20.3 kilotons of TNT.

A total of 9 vessels sank or capsized as a result of the explosion; they were situated in the range; 0 to 845-yd horizontal distance from the projected Zeropoint. (Distances are measured to nearest point of vessel.) Five (non-sunk) vessels were immobilized; they were situated at ranges from 465 yd to 640 yd.

Three other vessels, at ranges of 815 to 1030 yd, suffered at least temporary serious loss of military efficiency.

Moderate damage was inflicted on a B-17 drone flying 6000 ft directly above the Zeropoint.

Special radio and radar equipment exposed on decks of surface vessels was severely damaged at ranges as great as 700 yd. Data are lacking as to damage between 700 and 2000 yd. No important damage was suffered by deck-loaded equipment at 2000 yd or by equipment ashore at 5700 yd.

Although the animals were all situated in interior rooms on vessels located upwind from the Zeropoint, the great majority of them had died by 1 Nov 46. In nearly all cases, cause of death was gamma radiation. Dosages received varied from 310 roentgens (BRACKEN, at 1420 yd) to 2700 roentgens (GASCONADE, at 580 yd).

Many of the fish in the northeast corner of the Lagoon were killed by the explosion.

Values of peak pressure in the water half-way between surface and bottom were 7000, 4400, 1400, and 330 psi gage at 835, 1084, 2060, and 5000-ft, respectively, horizontal distance from the projected Zeropoint. At short ranges the pressure was somewhat less just beneath the surface than at greater depth.

The underwater shock wave had a velocity not appreciably different from the normal acoustical velocity.

Peak pressure in air was 4.8 psi gage at 1000-yd horizontal distance, or about the same as would have resulted from an air burst using 4 kilotons of TNT.

Optical radiation was negligible.

Nuclear radiations, particularly gamma-radiation, were very important. Between 10 and 50 percent of the radioactive material formed remained in the water or on target vessels. Total activity in the area corresponded (at one hour after Mike Hour) to roughly 5 X 10^9 curies (5000 megacuries), the approximate momentary equivalent of roughly 5000 tons of radium. Total radioactivity diminished approximately according to a $1/T^{1.3}$ law.

The area initially contaminated extended roughly 1800 yd upwind, 2 mi to each side, and downwind for 2 to 5 mi. Near the Zeropoint, the activity in the water decreased from about 400 roentgens per 24 hrs at one hour after Mike Hour to 0.1 roentgens per 24 hrs at five days after B-Day. Convection contributed, of course, to this decrease.

All but 9 of the target vessels were highly contaminated by the radioactive "rain" and base surge. Total gamma radiation dosages topside on the contaminated vessels ranged from roughly 300 roentgens to over 8000 roentgens. Typically, 50 percent of the dosage was "delivered" within the first 5 or 10 min; lethal dosages (400 roentgens) were delivered within 1 to 7 min in most cases.

In most (but not all) contaminated vessels, radioactivity below decks was less than ½ or even 1/10 as intense as topside.

Plutonium contamination of target vessels was sufficiently great to constitute a serious danger to persons boarding the target vessels days, weeks, or even months after B-Day (i.e., persons not already doomed by gamma radiation).

Decontamination efforts met with varying success. Earliest efforts (involving washing away loose materials) reduced the radioactivity by a factor of 2 to 5; but subsequent efforts produced smaller improvements.

Plutonium and radioactive fission products in the water were a danger to support vessels, since they tended to accumulate in evaporators and elsewhere.

The water directly above the bomb rose initially at a rate of 11,000 ft/sec. The height of column and cauliflower was 4100 ft at 10 sec and 7600 ft at 60 sec. Radius of the stem was 975 ft. Roughly 2,000,000 tons of water were contained in the column and cauliflower; the potential energy involved was approximately 10 percent of the total energy released in the explosion.

The condensation cloud reached its maximum radius (about one mile) at 4 sec after Mike Hour. By 30 sec it was essentially nonexistent.

The base surge formed approximately 10 sec after Mike Hour, and swept outward at 45 mi/hr, engulfing the majority of the target vessels in its radioactive mist. It attained a radius of approximately 8000 ft, and an altitude of approximately 2000 ft.

Waves had a maximum trough-to-crest height of 94 ft at a range of 1000 ft (horizontal distance from Zeropoint) and 9 ft at 12,000 ft. The first wave travelled with a velocity of 45 knots. The waves represented less than one percent of the total energy released in the explosion.

Waves probably made significant contributions to damage on at least five target vessels.

The crater produced in the Lagoon bottom was 25 ft deep; the net amount of bottom material moved was over 2,000,000 yd^3.

The explosion was detected at great distances (e.g., Continental U.S.) by earth shock and by radioactivity in the air.

The following Table presents estimates by the JTF-1 Technical Historian as to ranges at which specified loss of military efficiency during the first hour after Mike Hour is probable:

Extent of Immediate Loss of Military Efficiency	Range (yd)		
	Typical Ship Itself	Typical Crew Per Se	Ship and Crew in Combination
Very Serious	700	600	800
Serious	900	800	950
Moderate	1000	1000	1300
Slight	1500	2000	2000

The corresponding ranges for long term (i.e., first month) loss of military efficiency of crew per se would be: 2500, 2800, 3200, and 4000 yd.

Injury might be reduced by (1) fleeing from the fall-out and base surge, (2) getting below decks, (3) designing watertight and "quick-shedding," non-porous superstructures, (4) immediately stopping pumps taking water into the ship, (5) promptly washing off exposed areas, (6) detecting and preventing access to "hottest" areas, (7) providing disposable clothing, and (8) transferring crew to uncontaminated ship as soon as possible.

Mechanical and electrical damage to vessels was caused principally by the shock wave in water, and, to a lesser degree, water waves and shock wave in air.

Gamma radiation would have been the outstanding cause of short and long term injury to crews. Topside personnel within 1700 yd would receive lethal (400 roentgens) doses within 1 to 7 min. Considerable harm would result even to personnel on vessels at 4000 yd. Only moderate protection would be afforded personnel below decks on "typical" types of vessels.

Alpha radiation from plutonium inhaled, ingested, etc., may prove fatal over a period of years. Fifty to 100 micrograms may be a fatal dose. Dangerous concentrations may exist on contaminated vessels for months.

There were no technical or operational shortcomings of any significance; Test B was an entire success. The bomb was detonated at the correct time and position, and extensive graded damage was produced as desired. The instrumentation program was completed very satisfactorily; damage inspection was completed as promptly as radiological clearance permitted.

The very great importance of radioactive contamination by fission products was fully explored, and the insidious potentialities of plutonium contamination were brought to light. The Test was the world's fifth test of the atomic bomb, but it was the first test in which the radioactive "poisonous" material remained in the "biosphere," and thus presented a lingering and invisible menace to man and other forms of life.

A beginning was made at developing methods of decontamination; radioactive vessels were made available for continuing research and training in radiological decontamination, a field now known to be of prime importance.

Comparisons.

Aspect Compared	Test A	Test B	Remarks
Energy release	19.1 kilotons TNT	20.3 kilotons TNT	Remarkably alike; essentially the same as the values for Trinity and Nagasaki. Energy release at Hiroshima was appreciably less.
Number of vessels wholly or partly within 1000 yd	18 (4 of these were within 500 yd)	19 (6 of these were within 500 yd)	
Number of vessels sunk	5	9	This comparison is almost irrelevant as the target arrays were dissimilar.
Number of non-sunk vessels immobilized by mechanical or electrical damage.	6	5	Same comment as above.
Injury to animals	-	-	No meaningful comparison possible.
Pressure in air at 1000 yd	10.5 psi gage	4.8 psi gage	As regards pressure in air, Test B was equivalent to an air burst of 4 kilotons TNT.

(con't.)

Aspect Compared	Test A	Test B	Remarks
Optical Radiation	very intense (See Sec. 17.002)	negligible	
Period of intense gamma radiation	99 percent of dosage was delivered within the first 10 sec (45 percent within the first second)	Several days or weeks	
Maximum time-integrated gamma-radiation dosage topside on target vessel at 1000 yd	1800 roentgens	Approximately 10,000 roentgens	Test-B value depended greatly on wind direction.
Effect of alpha radiation	Negligible at all times	Would be fatal even to persons reboarding contaminated target vessels months after the explosion. (Fatalities might result from ingestion, inhaling, etc., of very small quantities of plutonium, which is alpha-radioactive.	-
Effect of neutron radiation	Fatal within 450 yd even to below-deck personnel	Negligible (except indirectly through formation of radio-sodium)	-
Disposition of fission products	Carried away in the mushroom and cloud	10 to 50 percent remain in the target area water and vessels	The very harmful gamma radioactivity decreases according to $1/T^{1.3}$ law.

(con't.)

Aspect Compared	Test A	Test B	Remarks
Disposition of Plutonium	Same as above.	Same as above.	The harmful and insidious alpha-radioactivity diminishes very little over periods of months or years.
Horizontal range at which probability is 50 percent that a surface combatant vessel itself will suffer immediate (i.e., first hour) loss of military efficiency:			
Very serious loss	900	700	In each case the greater value (Test A versus Test B) is underlined.
Serious loss	1000	900	
Moderate loss	1300	1000	
Slight loss	1500	1500	
Same, but for crews per se			
Very serious loss	700	600	-
Serious loss	800	800	
Moderate loss	900	1000	
Slight loss	1000	2000	
Same, but for vessels and crews in combination			
Very serious loss	900	800	-
Serious loss	1020	950	
Moderate loss	1300	1300	
Slight loss	1500	2000	
Same, but for long term effect on crews per se			
Very serious loss	800	2500	-
Serious loss	1100	2800	
Moderate loss	1400	3200	
Slight loss	1700	4000	
Phenomena detectable at distances of thousands of miles.	Radioactivity in the air	Earth shock and perhaps radioactivity in the air	-

(con't.)

Aspect Compared	Test A	Test B	Remarks
Period in which Lagoon was dangerously contaminated	Less than one hr.	One to two weeks.	Lagoon water "changes" in 1 or 2 months.
Period in which target vessels were appreciably contaminated	Less than one day, ordinarily	Weeks or months	In Test B, the period can be very greatly shortened by decontamination measures.

Termination.

On 31 Oct 46 Joint Task Force One was dissolved. Most of the target vessels had been re-assigned by that date. Decontamination and research on decontamination methods were continuing.

On 7 Sept 46, the President announced the indefinite postponement of Test C, the deep-underwater explosion originally scheduled for early 1947.

Chapter 1

Introduction

Outline

Section

Chapter 1

Introduction

1.001 Origin of Operation Crossroads.

A. Introduction. The Joint Chiefs of Staff, by memorandum SM-4700 of 11 Jan 46, formally created Joint Task Force One and charged it with determining the effects of atomic bombing of naval vessels. At the same time, and acting with Presidential approval, they designated Vice Adm. W. H. P. Blandy as Commander of the Task Force. They approved the code name Operation Crossroads on the following day.

B. Activities Leading up to the Creation of JTF-1.

1. Introduction. When was the Operation first conceived? No definite answer can be given to this question since the idea--or variations of it--occurred to various persons at various times. For example, as early as 1944 the Manhattan Engineer District had given serious consideration to "testing" its atomic bombs against the Japanese Navy at Truk Island. After the 6 Aug 45 announcement of the atomic bombing of Hiroshima, much public discussion arose as to what effect such a bomb might have on a naval ship or fleet.

Congress took an immediate interest in the atomic bomb and its potentialities. Senator Brien McMahon (D., Conn.) made a speech to the Senate on 25 Aug 45 in which he said: "In order to test the destructive powers of the atomic bomb against naval vessels, I would like to see these (Japanese naval) ships taken to sea and an atomic bomb dropped on them. The resulting explosion should prove to us just how effective the atomic bomb is when used against the giant naval ships. I can think of no better use for these Jap ships."

2. Early Activities at Joint Chiefs of Staff Level. On 18 Sept 45 the Joint Chiefs of Staff became formally involved in the proposals for holding atomic bomb tests. On that date, Gen H. H. Arnold, Commanding General of the Army Air Forces, recommended to the Joint Chiefs of Staff that the routine destruction of surviving Japanese naval vessels -- recommended on 28 Aug 45 by Adm. E. J. King, Commander-in-Chief of the U. S. Fleet and Chief of Naval Operations -- be countermanded. Gen. Arnold proposed that a number of these vessels be made available to the Army Air Forces for use in tests involving atomic bombs and other weapons. On 16 Oct 45 Adm. King recommended that the atomic bomb tests be controlled by the Joint Chiefs of Staff and conducted by the Navy with the assistance of other Service groups. He recommended that one bomb be

detonated in the air and another in the water, and that besides captured Japanese vessels, a few U. S. A. naval vessels of modern design should be used in the target array.

On 31 Oct 45 Gen. Arnold recommended that the Joint Chiefs of Staff direct the Joint Staff Planners (a permanent working committee of the Joint Chiefs of Staff) to determine what types of tests should be made and to suggest an agency to carry out such tests. The Joint Chiefs of Staff concurred with this recommendation on 9 Nov 45, and, on 10 Nov 45, issued the appropriate formal instructions to the Joint Staff Planners. On 13 Nov 45 the Joint Staff Planners created the "LeMay Subcommittee" (see Para. 5) to make the necessary studies and recommendations.

3. Army Activities. Perhaps the first formal proposal by a top War Department official for subjecting captured naval vessels to atomic bombs was the proposal made on 14 Sept 45 by Lt. Gen. B. M. Giles, Commanding General of the U. S. A. Strategic Air Forces. From his Tokyo headquarters he proposed that at least two atomic bombs be used in the destruction of the remnants of the Japanese fleet. His suggestion was forwarded on that same day (by telegram) by Maj. Gen. C. E. LeMay to Lt. Gen. C. A. Spaatz and also to Gen. H. H. Arnold -- who thereupon made to the Joint Chiefs of Staff the recommendation recorded in the foregoing Paragraph.

4. Navy Activities. On 28 Aug 45 Vice Adm. E. L. Cochrane, Chief of the Bureau of Ships, informed his design and research groups that the Bureau of Ships "must be prepared to undertake broad-scale experiments with the atomic bomb to clear up its major influence on naval warfare." (Paradoxically, Adm. King, Commander-in-Chief of the U. S. Fleet and Chief of Naval Operations, recommended on that same day to the Joint Chiefs of Staff that the surviving Japanese naval vessels be destroyed in routine manner in Japanese home water. Fortunately, the Secretary of State being out of this country, no action was taken on this recommendation.)

On 1 Oct 45 Vice Adm. E. L. Cochrane and R. Adm. (now V. Adm.) G. F. Hussey, Jr., sent a letter to the Chief of Naval Operations stating that the appearance of the atomic bomb "has made it imperative that a program of full-scale testing be undertaken to determine the effects of this type of bomb, both underwater and above water, against ships of various types." This letter, which outlines the problem at considerable length, added that the two bureaus would "prepare and present for consideration at the earliest practicable date a testing program with the atomic bomb including specific ship requirements." Requesting that various warships already scheduled for disposal be retained for the atomic bomb tests, the letter pointed out the serious shortcomings of model work and the need for realistic tests. It explained that certain of the proposed postwar design developments in underwater ordnance and in underwater protection require "realistic ship targets, either by virtue of the inherent nature of the problem, or to provide adequate guidance so that model work and simplified experiments may be prosecuted intelligently."

On 16 Oct 45 Adm. King made the recommendation discussed in a previous paragraph to the effect that the Joint Chiefs of Staff control the tests; that the Navy, with the assistance of the other Service branches, carry out the tests; that, besides captured Japanese vessels, a few U. S. A. naval vessels of modern design should be used in the target array.

5. Activities of the LeMay Subcommittee. The LeMay Subcommittee, created by the Joint Staff Planners on 13 Nov 45, had the following membership (after three early changes):

Maj. Gen. C. E. LeMay (Steering Member)
Brig. Gen. W. A. Borden
Col. C. H. Bonesteel
Capt. G. W. Anderson, Jr. (Navy)
Capt. V. L. Pottle, (Navy)
Commo. (now R. Adm.) W. S. Parsons

Charged with making the necessary studies and recommendations, this Subcommittee held several discussions between 13 Nov 45 and 22 Dec 45, covering all major technical and administrative problems. One matter discussed in especially great detail was the question as to who should be chosen as Task Force Commander. The Army Air Forces members of the Subcommittee favored designating Maj. Gen. L. R. Groves, Commanding General of the Manhattan Engineer District, but it was finally decided that since the majority of the planning and execution would be in Naval domain, a Naval officer should be designated. On 15 Dec 45 the senior Navy member of the Subcommittee, Commo. (now R. Adm.) W. S. Parsons, proposed that Vice Adm. W. H. P. Blandy be selected in view of his experience as Commander of various destroyer groups, cruiser groups, and amphibious groups, and in view of his position since Nov 45 as Deputy Chief of Naval Operations, Special Weapons.

On 21 Dec 45 the Subcommittee discussed a preliminary draft of its report with the Military Advisory Board to the Officer-in-Charge of the Atomic Bomb Project. Some changes were made in the draft, including provisions to give the Task Force Commander broader authority.

C. Final Acts by Joint Chiefs of Staff and by the President in Creating JTF-1. The preliminary findings and recommendations by the Joint Staff Planners, based on the work of the LeMay Subcommittee.

were presented to the Joint Chiefs of Staff in a report dated 22 Dec 45. This report, with minor amendment, was approved informally by the Joint Chiefs of Staff on 28 Dec 45, approval extending not only to the creation of the Joint Task Force and the defining of its purposes, but also to the selection of Vice Adm. Blandy as Commander. A few days later Vice Adm. Blandy presented a detailed administrative and technical plan. This plan was transmitted by the Joint Staff Planners to the Joint Chiefs of Staff on 10 Jan 46, and at the same time attention was called to the necessity of obtaining Presidential approval. (Actually such approval had been requested by the Secretaries of War and Navy on 8 Jan 46.) On 10 Jan 46 the President gave his approval; on the letter he had received from the Secretaries of War and Navy he wrote "Approved Jan. 10, 1946. (signed) Harry S. Truman."

D. Directive to Vice Admiral W. H. P. Blandy. On 11 Jan 46, accordingly, Vice Adm. Blandy received formal notification from the Joint Chiefs of Staff of his designation as Commander of Joint Task Force One. The directive addressed to him read as follows:

> 1. By direction of the President, you are designated commander of a task force under the Joint Chiefs of Staff for the purpose of conducting tests for the determination of the effects of atomic explosives against naval vessels in order to appraise the strategic implications of the application of atomic bombs including the results on naval design and tactics. You will organize a joint staff with adequate representation of land, sea, and air forces. You will include civilian scientists in your organization.
>
> 2. The general requirements of the test will be to determine the effects of atomic explosives against ships selected to give good representation of construction of modern naval and merchant vessels suitably disposed to give a gradation of damage from maximum to minimum. It is desired to include in the tests both air detonation and underwater detonation if the latter is considered feasible. Tests should be so arranged as to take advantage of opportunities to obtain the effects of atomic explosives against ground and air targets and to acquire scientific data of general value if this is practicable.
>
> 3. You are authorized to deal directly with agencies of the War and Navy Departments in all matters relating to the preparation for the conduct of these tests, including direct access to the Manhattan District. Usual service lines will be available for administrative and logistic support of forces assigned to the project.

4. The Joint Chiefs of Staff will appoint as a separate agency, directly responsible to them, an evaluation board (committee) for the express purpose of evaluating the results of the tests. This board will be available to you for advice during the preparation of the tests. Appropriate sections of your organization will collaborate with this board as necessary, and you will provide it with all necessary facilities it may require to fulfill its functions.

5. You will prepare plans for the test including selection of a suitable site which will permit accomplishment of the tests with acceptable risk and minimum hazard. Your plans for the operation and final report will be submitted to the Joint Chiefs of Staff for their approval.

For the Joint Chiefs of Staff:
/s/ A. J. McFarland
Brigadier General, U. S. A.
Secretary

1.002 Choice of Site.

In accordance with the recommendation of Vice Adm. Blandy on 21 Jan 46, the site designated for the atomic bomb tests was the lagoon of Bikini Atoll lying at Latitude 11° 31' North, Longitude 165° 34' East, in the Marshall Islands, Pacific Ocean. (see Chap. 4)

Fig. 1.1 is a map showing the location of Bikini Atoll in the Pacific Ocean. (In Chap. 4 a detailed map of Bikini Atoll itself is presented.)

This site was selected after consideration of a great many sites and in the light of these desired characteristics:

Protected anchorage at least six miles in diameter.
Unpopulated region situated at least 300 miles from urban areas.
Location less than 1000 mi from B-29 base.
Location free of violent storms.
Predictable winds directionally uniform at all altitudes from sea-level to 60,000 ft.
Predictable currents of great lateral and vertical dispersion; fast currents avoiding fishing areas, steamer lanes, inhabited shores.
Minimum distance from continental United States.
Owned or controlled by the United States.
Temperate or tropical climate.

Except for its population of 167 (which could presumably be evacuated) Bikini Atoll met these requirements reasonably well.

On 23 Jan 46 the Department of the Interior's Fish and Wildlife Service declared authoritatively that no appreciable damage to fishery resources would result from the explosions at the Bikini site.

A later chapter discusses shortcomings of the site as regards currents.

1.003 Activities by the President.

President Truman was no newcomer to the field of atomic energy. Soon after his inauguration he had been brought into the discussions leading up to the epoch-making decision to use atomic bombs against Japan. Recognizing the portent of the Nucleonics Age, he took immediate steps in the direction of adequate national and international control. His 3 Oct 45 message to Congress dealt with national control, and the 15 Nov 45 declaration made jointly with Prime Minister C. R. Attlee of Great Britain and Prime Minister W. L. MacKenzie King of Canada dealt with international control.

On 10 Dec 45 the President approved the proposed atomic bomb tests against Naval vessels and that such tests were to be a joint undertaking.

On 10 Jan 46 he approved the general plan proposed by the Joint Chiefs of Staff.

On 8 Feb 46, in reply to a letter to Senator Brien McMahon, the President indicated his intention of having certain key civilian advisers witness the Tests.

On 22 Mar 46 the President directed that the tests be postponed approximately six weeks in order that the Congressional observers could complete their current legislative work and yet witness the Tests.

On 30 Mar 46 the President announced the membership of a "President's Evaluation Commission" composed of civilians to witness the Tests.

To remove any doubts in the minds of the public and the members of Congress as to his confidence in, and approval of, the proposed Tests, the President issued on 12 Apr 46 a short statement approving the plans.

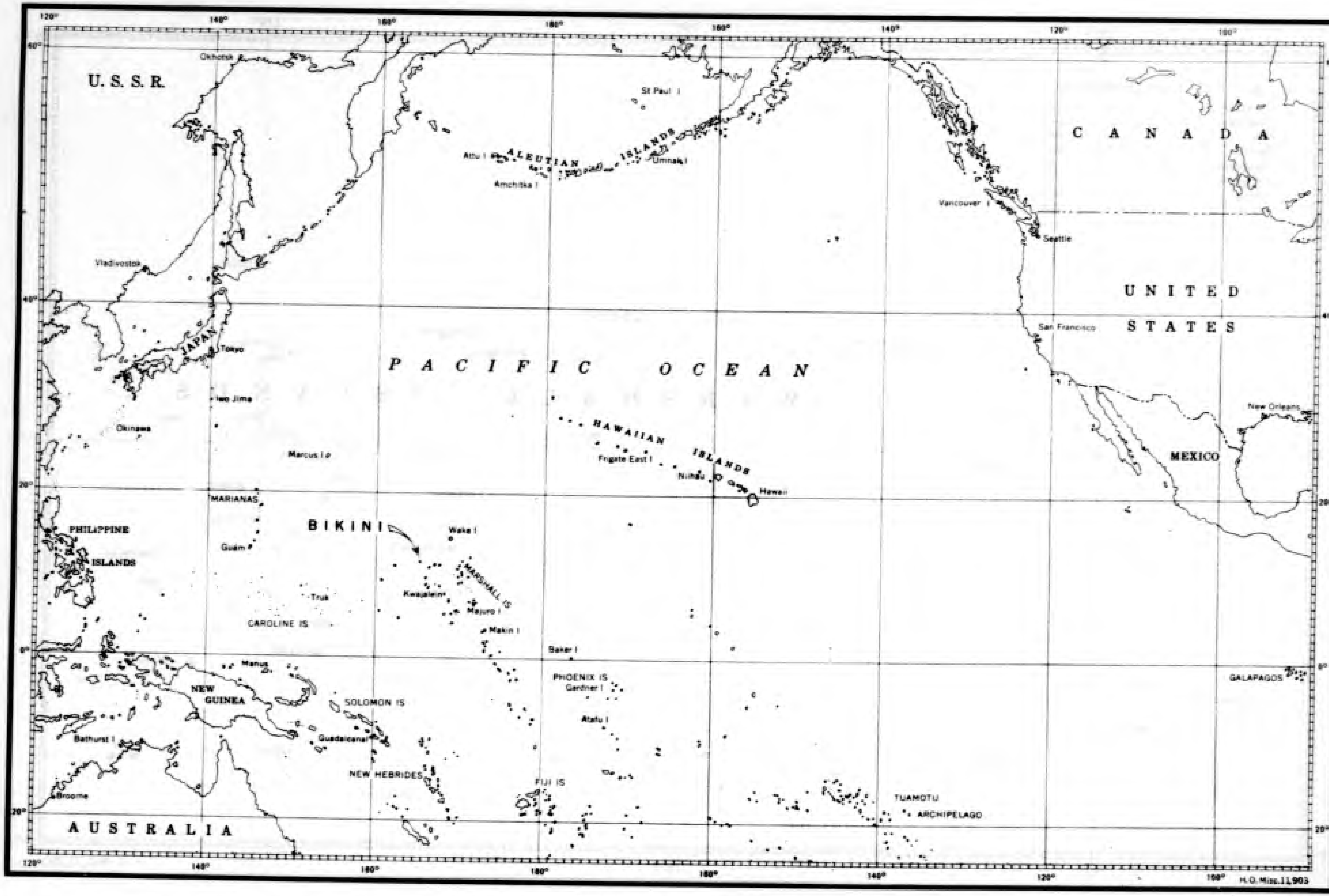

FIGURE 1.1—MAP OF PACIFIC OCEAN SHOWING LOCATION OF BIKINI

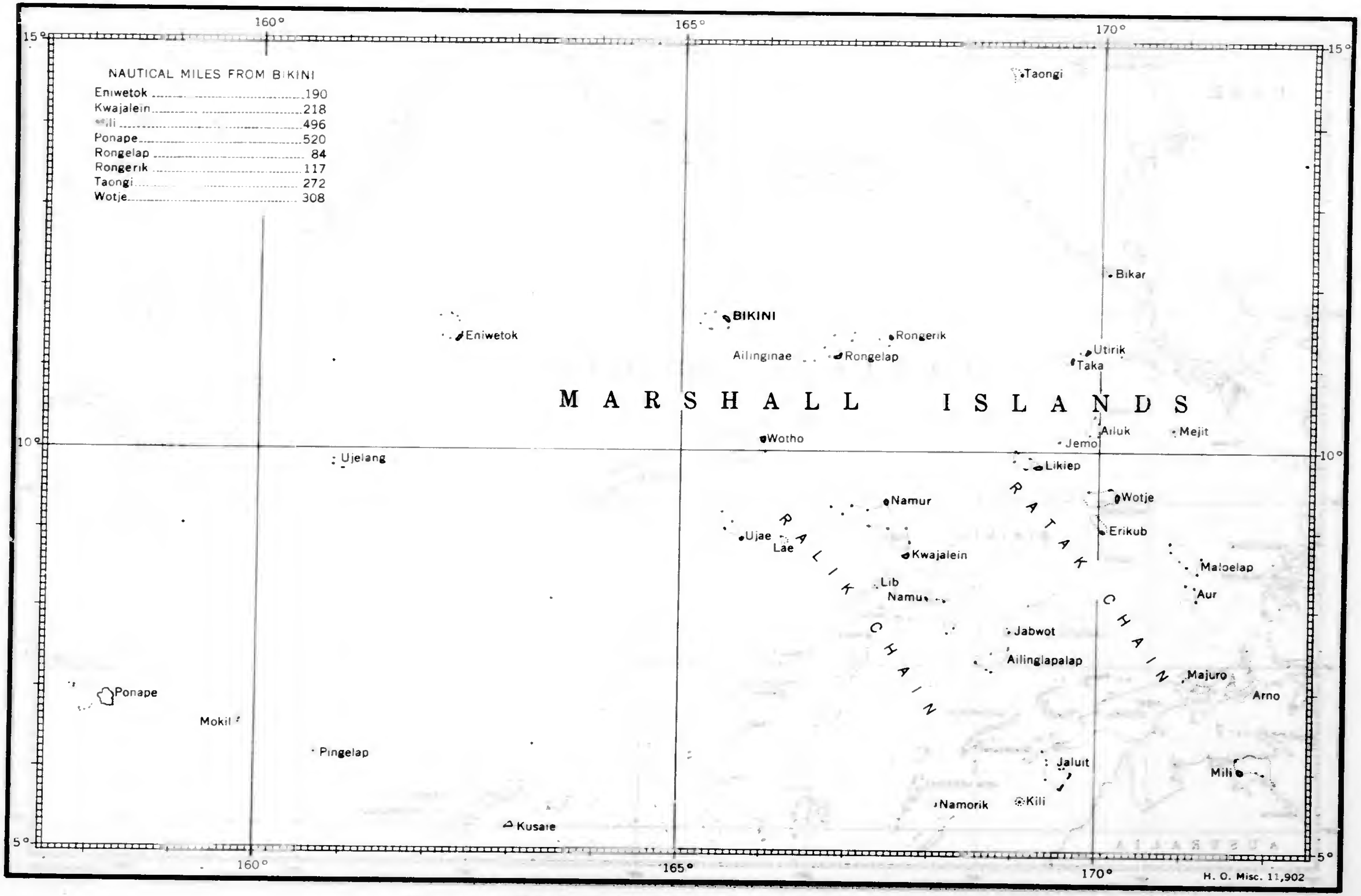

FIGURE 1.1a—MAP OF MARSHALL ISLANDS

Soon after Test A the President released preliminary reports by the Evaluation Board and the President's Evaluation Commission on the outcome of the Test. Corresponding releases were made soon after Test B.

1.004 Activities of Congress.

A. Introduction. Although prior to 5 Aug 45, Congress as a whole had very little knowledge of the atomic bomb project, Congress took much interest in the matter immediately following use of the bombs over Japan. Both the Senate and the House initiated legislation designed to control military and peacetime uses of atomic energy. In all, over twenty different bills in this field were introduced. Senator Brien McMahon's bill, now called "The Atomic Energy Act of 1946," won out and became law on 1 Aug 46.

B. Authorization for Use of Vessels as Targets. Congressional authorization for the use of 33 U. S. combatant vessels as targets was given on 14 June 46--i.e., only seventeen days prior to Test A. The House and Senate actions are discussed separately below.

1. House Action. House Joint Resolution 307 was introduced on 28 Jan 46 by Representative Carl Vinson, Chairman of the House Committee on Naval Affairs, to provide the necessary authorization for using certain vessels as targets. This Resolution was approved by the House on 12 Mar 46.

2. Senate Action. House Joint Resolution 307 did not meet with ready acceptance in the Senate. Some Senators, notably Senators J. W. Huffman of Ohio and S. W. Lucas of Illinois, urged that the tests be cancelled for a number of reasons ranging from technical and fiscal to international-political. On 18 Apr 46 Senator Huffman introduced House Concurrent Resolution 146 to the effect "that the President is hereby requested to cancel the two atomic bomb tests scheduled." (This resolution was referred to the Committee on Foreign Affairs, and died.)

In a letter of 1 Apr 46, Senator D. I. Walsh indicated to the Secretary of the Navy that favorable action by the Senate on House Joint Resolution 307 would be more readily obtained if a resurvey were made and reported as to the minimum number of target vessels essential to the Tests. He pointed out also that the President's postponement of the Tests and the subsequent uncertainty in some quarters as to whether the President was wholeheartedly in favor of the Tests was interfering with prompt favorable action by the Senate.

The various hindrances to favorable Senate action were overcome. On 12 Apr 46 the White House released a short statement by the President demonstrating his complete confidence in, and approval of, the forthcoming Tests; on 12 Apr 46 Vice Adm. Blandy presented the results of his resurvey of the minimum requirements as to target vessels; and on 17 Apr 46, Capt. I. H. Nunn, Navy Legislative Counsel, presented a proposed revision which would make good the shortcomings of the original form of H. J. Res. 307. Senate approval of the modified bill was finally obtained on 14 June 46. It was signed by the President that same day.

1.005 The Evaluation Board.

A. Creation. In their directive of 11 Jan 46 to Vice Adm. W. H. P. Blandy, the Joint Chiefs of Staff recorded their intention of creating an Evaluation Board having these functions: (1) To be available for advising Commander JTF-1 in his planning of the Tests; (2) To prepare and present to the Joint Chiefs of Staff an evaluation of the results of the Tests. (These duties had been proposed to the Joint Chiefs of Staff by the Joint Staff Planners.)

The Board was duly appointed, the civilian members being chosen by the Secretaries of War and Navy and the military members being appointed by the Joint Chiefs of Staff.

At its first meeting, on 28 Feb 46, the Board elected a chairman and a vice chairman. The complete membership, which was announced by Vice Adm. Blandy on 28 Mar 46, was as follows:

- Dr. K. T. Compton, President of the Massachusetts Institute of Technology, Cambridge, Mass. (Chairman)
- Mr. Bradley Dewey, President of the American Chemical Society and President of the Dewey and Almy Chemical Co., Cambridge, Mass. (Vice-Chairman)
- Mr. T. F. Farrell, Chief Engineer of the New York State Department of Public Works, Albany, New York; formerly Major General in the Manhattan Engineer District.
- Gen. J. W. Stilwell, Commanding General, Sixth Army Area.
- Lt. Gen. L. H. Brereton, on Special Duty in the Office of the Secretary of War; formerly Commanding General, First Air Force.
- Vice Adm. J. H. Hoover, a member of the Navy General Board.
- R. Adm. R. A. Ofstie, Senior Navy Member of the U. S. Strategic Bombing Survey.

B. Activities. The Board met with Vice Adm. Blandy's staff several times before the Tests (see Fig. 1.2), examined the plans,

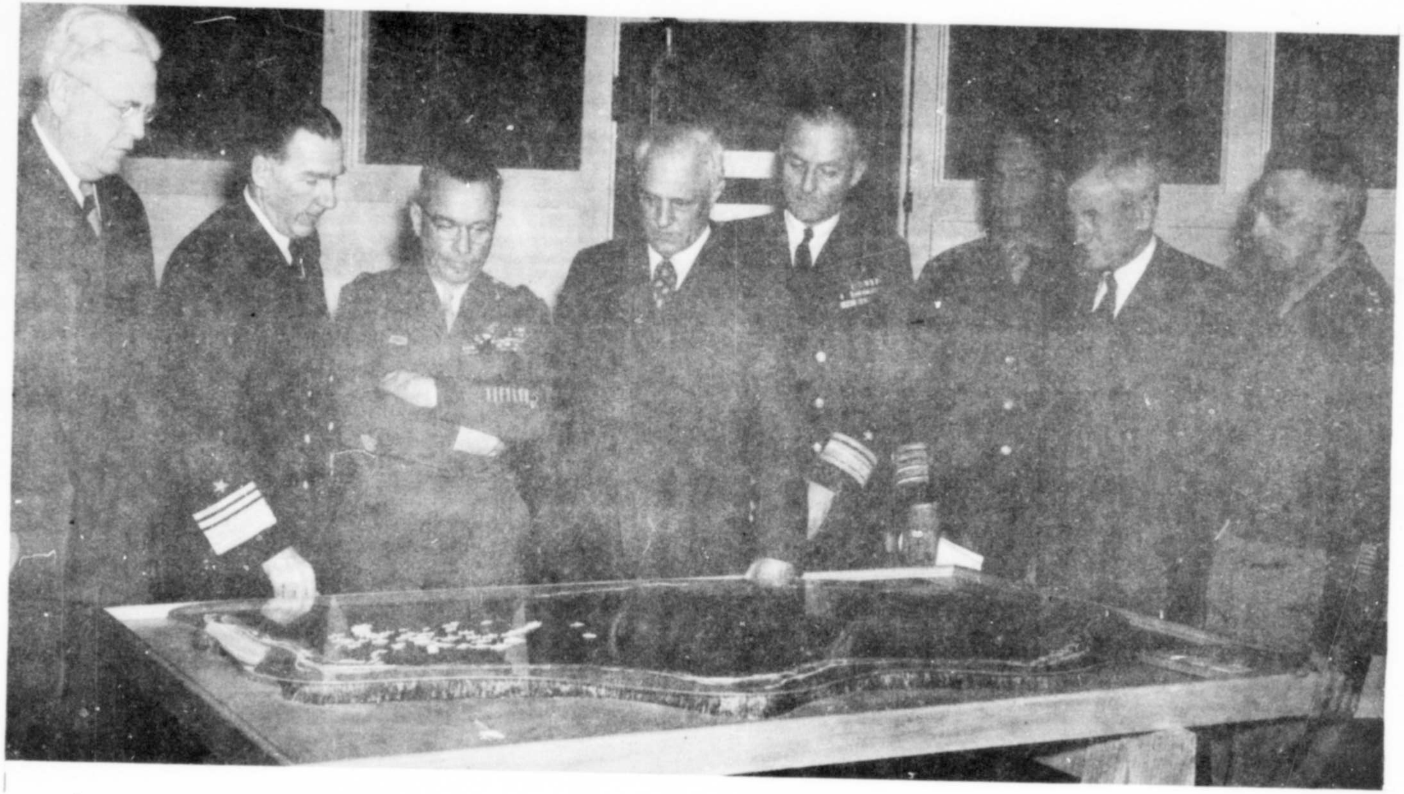

Figure 1.2 Commander JTF-1 Receiving the Evaluation Board

made suggestions as to fuel loads on target vessels, and requested information on the strengths of vessels' hulls.

The Board members flew to Bikini, arriving there on 29 June 46. They inspected some of the target ships just before Test A, witnessed the Test A explosion from an airplane twenty miles distant, approached almost immediately to within nine miles for a brief view, and began their systematic inspection of the more interesting target vessels on the following day.

For Test B, the Board divided into two groups. Four members were airborne and witnessed the explosion from a distance of eight miles and from an altitude of 7500 feet. The other three members were aboard the HAVEN and observed the explosion from a distance of eleven miles.

The Board issued, through the Joint Chiefs of Staff and the White House, a preliminary brief report on Test A (on 11 July 46) and a similar report on Test B (on 2 Aug 46). These reports are presented in later chapters.

The Board expressed complete satisfaction with the execution and results of the two Tests.

The Board's final study and recommendations are awaiting appearance of the main technical reports on the Tests.

<u>1.006 The President's Evaluation Commission.</u>

<u>A. Creation.</u> The membership of the President's Evaluation Commission was announced publicly on 30 Mar 46. Creation of such an ad hoc group of observers had been suggested to the President on 6 Feb 46 by Senator Brien McMahon, who felt that public confidence in the Tests would be increased greatly by the existence of a reporting group of nonmilitary men of recognized ability and impartiality.

The finally arranged membership was as follows:

Senator C. A. Hatch, New Mexico (Chairman)
Senator Leverett Saltonstall, Massachusetts
Representative W. C. Andrews, New York
Representative Chet Holifield, California
Dr. K. T. Compton, President of the Massachusetts Institute of Technology, Cambridge, Mass.

Dr. E. U. Condon, Director of the National Bureau of Standards, Washington, D. C., and Scientific Adviser to the Senate's Special Committee on Atomic Energy
Mr. Bradley Dewey, President of the American Chemical Society and President of the Dewey and Almy Chemical Co., Cambridge, Mass.
Mr. W. S. Newell, President of the Bath Iron Works Corporation, Bath, Maine
Mr. Fred Searls, Jr., mining engineer and special assistant to the Secretary of State

(Earlier, Representative A. J. May, Kentucky, had been Vice-Chairman of the Commission; and Dr. J. R. Oppenheimer, former Director of the Los Alamos Laboratory, had been a member. Both of these men resigned prior to Test A.)

B. Activities. The Commission held its first formal meeting with Commander JTF-1 on 30 Mar 46. The Chairman of the Commission was elected at a meeting 3 May 46.

The President gave the Commission its general directive on 18 May 46. He specified these functions: (a) To cooperate with the Secretaries of War and of Navy in the conduct of the Tests; (b) To undertake a study of the Tests and submit to the President the Commission's observations, findings, conclusions, and recommendations.

Throughout the Operation, the Commission joined the Evaluation Board in various conferences and inspection trips. No attempt was made to exchange or coordinate their respective conclusions, although, of course, two members of the Commission were also members of the Evaluation Board.

During Test A, some members of the Commission were aboard airplanes; others were on surface vessels. During Test B, seven members made their observations from the HAVEN eleven miles distant.

The Commission released through the White House a preliminary report dated 11 July 46 on Test A, and a similar report dated 29 July 46 on Test B.

The Commission commended Commander JTF-1 on the execution of the Tests.

1.007 Public Reaction to the Tests as Planned.

The public press and radio displayed great interest in the Tests immediately following the formal announcement on 10 Dec 45 that such

Tests would be held. In the following months, the picture magazines, newspaper Sunday supplements, and broadcasts abounded with discussions of all kinds. While much comment was favorable, some was unfavorable. Some critics contended: that the Tests were designed to prove the Navy obsolete, or not obsolete; or that the target array was supposed to represent a fleet steaming in open ocean; that the Tests were designed to impress other countries with the destructiveness of our new weapon; or that various catastrophies would result, as from tidal waves or chain reactions initiated in the ocean itself. Examples of unfavorable comments on the proposed Tests are: a full-page advertisement by an official of the Order of the Purple Heart commenting unfavorably on the Tests, which appeared in New York and Washington newspapers in late Feb 46; a letter to the editor of the "New York Times" by Dean L. A. DuBridge of the University of Rochester, (present head of the California Institute of Technology) the letter appearing in the 5 May 46 issue. By 1 June 46, approximately 7000 letters of protest, the majority of them opposing use of animals, were received by JTF-1 from the public.

In early April, the Gallup Poll found that 47 percent of the public approved and 35 percent opposed the continuing of the atomic bomb test program, and 18 percent had no opinion on the subject.

Chapter 2

Objects of the Tests

Outline

Section

Chapter 2

Objects of the Tests

2.001 Introduction.

According to directive SM 4700 issued by the Joint Chiefs of Staff to Commander JTF-1 on 11 Jan 46, the objects of the Tests were:

> "...the determination of the effects of atomic explosives against naval vessels in order to appraise the strategic implications of the application of atomic bombs including the results on naval design and tactics....The general requirements of the test will be to determine the effects of atomic explosives against ships selected to give good representation of construction of modern naval and merchant vessels suitably disposed to give a gradation of damage from maximum to minimum. It is desired to include in the tests both air detonation and underwater detonation if the latter is considered feasible. Tests should be so arranged as to take advantage of opportunities to obtain the effects of atomic explosives against ground and air targets and to acquire scientific data of general value if this is practicable..."

This Chapter discusses in some detail the various objects which emerged in the early planning. It also analyzes the attainability of these objects.

2.002 Principal Military Objects.

The principal military objects of the Tests were:

(1) Determining principal effects on ships. This object included determining what mechanical damage would be done by the blast to vessels as wholes, to ship hulls, machinery, fuel tanks, etc.; determining the relative vulnerabilities of different types of vessels and different classes of vessels; determining how the various vulnerabilities vary with distance from the detonation point; determining corresponding data for damage produced by heat radiated from the detonation region; determining what damage would be done by underwater shock waves.

(2) Determining principal effects on ships crews. This included determining effects on personnel of radiation blast (optical,

thermal, ultraviolet, gamma rays, and neutrons), air blast, solid blast (flying fragments of whatever origin), and water blast. It included determinations of the variations in injury with distance from the detonation point, with location of personnel in the ships, and with various degrees of protection.

(3) Determining the best means of decontaminating vessels and equipment rendered radioactive.

(4) Obtaining sufficient data on the pressures and accelerations causing serious damage, to permit naval architects and engineers to design more resistant ships.

2.003 Lesser Military Objects.

Among the lesser military objects of the Tests were these:

(1) Providing the Army Air Forces with experience in bombing naval vessels. This included experience in loading and transporting the bomb, recognizing the desired target, making the very high-altitude bombing run, releasing the bomb, making safe get-away, and making effective use of airborne instruments for appraising the detonation.

(2) Determining the effects of the explosion on a variety of military equipment. This included effects on airplanes, tanks, trucks, radio and radar installations, ammunition, fire control systems, food, clothing, medicine, etc.

2.004 Principal Scientific and Technical Objects.

The principal scientific and technical objects of the Tests were as follows:

(1) Determining the kinds and extents of biological and chemical effects produced by radiations of all kinds. This included effects produced on simulated crew personnel (animals) by ultraviolet, visible, and infrared light, by newtrons and gamma rays, by radioactivity from fission products, and by induced radioactivity; it included studies on the effectiveness of special protective materials; it included also effects on bacteria, seeds, medical equipment, and supplies.

(2) Determining diagnosis and treatment of injurious radioactive effects on simulated crew personnel (animals).

(3) Learning more about the transmission of intense shock waves in air and water; developing improved instruments for measuring these phenomena.

(4) Learning more about the optical and gamma radiation produced by an atomic bomb.

(5) Finding what fraction of the energy released in a shallow underwater atomic bomb explosion goes into the water (to be transmitted by the shock wave, transmitted by surface waves, or converted into thermal energy), and what fraction goes into the column or into the air.

(6) Obtaining oceanographic information on production and propagation of water waves.

(7) Determining to what extent atomic bomb explosions may be detected (as for intelligence purposes) at distances of thousands of miles.

(8) Obtaining seismographic information on the nature and speed of propagation of waves in the earth; also determining the character of the solid structures supporting the coral atoll.

(9) Finding new atmospheric ionization and electrostatic effects, including abnormal reflection and propagation of radio and radar waves.

(10) Obtaining meteorological data associated with the development of the clouds, creation of fog zones, production of winds, and dispersion of fission products in air.

(11) Obtaining data on the large scale inducing of radioactivity in common materials.

<u>2.005 A Priori Attainability of Objects.</u>

Throughout the course of preparation for the Tests, the impossibility of fully achieving all the goals was realized. The principal immutable obstacles were these:

<u>A. Lack of Time.</u> The Tests had to be held this year rather than a later year in order that Nucleonics Age naval planning could begin. Furthermore, a large fraction of the civilian scientific personnel and an appreciable fraction of the military personnel were committed to returning to normal peacetime pursuits on or about 1 Sept 46. Finally, budget cuts were in prospect. As a result, it was

necessary to schedule the Tests not later than July or early August. This meant that attempts to design and build some of the less important instruments of specialized type had to be abandoned; and there was not always time for adequate inspecting, testing, and rehearsing.

B. Insufficient Personnel. The personnel situation was extremely tight throughout the operation. This was particularly true of divers, electronics personnel, and various other types of technical personnel. As a result of actual or threatened shortage of personnel, various parts of the program had to be restricted in scope.

C. Necessity of Using Inferior Ships. For reasons of economy, it was necessary to use inferior ships--U. S. Naval ships which were old or damaged and captured enemy ships. In many important respects these ships were not closely comparable to modern U. S. Naval construction. Furthermore, watertightness was imperfect in some cases. Expectations were that rough "correction" of damage data (to make them applicable to modern types of U. S. ships) would have to be made for some of the ships.

D. Uncertainty as to Radius of Damage. Because it was not known within close limits what the radius of damage would be for various kinds of ships and material, the optimum locations for instruments were not known. This made it necessary to "over-disperse" the target vessels and instruments--so that while some might be too near the detonation point and some too far away, a few, at least, would be at favorable distances.

E. Uncertainty as to Accuracy of Bombardier's Aim. Allowance had to be made for possible errors in the bombardier's aim.

F. Unavoidable Destruction of Instruments. It was obvious that a good many instruments would be lost or rendered useless by various secondary effects such as uncontrolled fires, uncontrolled floodings, and sinkings--in addition to instruments destroyed by the explosion proper.

G. Partial Incompatibility of Tactical and Scientific Objects. Since tactical as well as scientific results were desired, the Tests could not be designed to be most favorable for either. Frequent compromises were necessary.

2.006 Extent to Which Objects were Realized in the 1945 Explosions.

Why, it may be asked, were the Crossroads tests necessary? Was not the information obtained from the atomic bombs exploded at

Alamogordo, Hiroshima, and Nagasaki adequate? (A number of recognized scientists not connected with JTF-1 raised such questions, which were perhaps most succinctly stated by Dr. L. A. DuBridge then of Rochester University, in a letter appearing in the "New York Times" for 5 May 46.) The fact is that although these three explosions were highly successful from a military point of view and even successful in certain scientific respects, there were appreciable gaps in the scientific information obtained. The principal shortcomings are described in the following:

A. Trinity Explosion. The Trinity explosion, which took place at Alamogordo, N. M., at 1130 on 16 July 45, (G.C.T.) was a complete success from the military point of view, and much scientific information was gathered -- particularly as regards gamma radiation, neutron radiation. On the other hand, the optical radiation and pressure data were not as extensive or accurate as had been hoped. These shortcomings are understandable in view of the following circumstances: (1) due to general lack of time, preoccupation with getting other bombs ready for use over Japan, and the general difficulty of rapidly assembling highly specialized equipment, the instrumentation was not as complete as desired, and testing of instruments had to be done very rapidly; (2) some of the men setting up and operating the instruments were nearly exhausted from overwork and lack of sleep, especially in the two or three days immediately preceding the explosion; (3) the explosion was considerably more violent than had been expected. Some instruments had been placed too near the Zeropoint, or were too lightly constructed and anchored.

B. Hiroshima Explosion. The Hiroshima explosion, which occurred at 2315 on 5 Aug 46 (G.C.T.), was amazingly successful militarily; but practically no measurements were made of radiation or pressure, and injury-to-personnel data, although extensive, were not fully adequate.

1. Radiation and Pressure Data. A few photographs were obtained showing the general appearance of the cloud, but none of these permitted qualitative or quantitative analysis of the optical radiation. No measurements were made of the abundances of gamma rays and neutrons emerging from the detonation. Pressure data were obtainable only from radiosondes; these lacked adequate calibration, and their locations (relative to the Zeropoint) were not accurately known.

2. Data on Injury to Personnel. Studies made of injuries to Hiroshima personnel have provided a great deal of useful information, particularly as to types of injury; but from the scientific point of view the information was appreciably incomplete, for the following reasons:

(a) The injured received little or no medical attention, with the result that what probably should have been relatively trivial injury often turned out to be serious.

(b) Injured and uninjured suffered from the ensuing fires and floods, and from the shortage of food and shelter.

(c) A majority of the officials who might have been active in determining the statistics of injuries were themselves killed or injured.

(d) Fire and flood eliminated much of the evidence.

(e) Many of the survivors fled.

(f) Since survey teams did not arrive on the scene until three to six weeks after the detonation, they were unable to study early-stage cases.

(g) Witnesses interviewed had very imperfect and inconsistent recollections, and, in testifying, they usually showed greater desire to please the interviewer than to be accurate.

(h) In view of the lack of data on pressure values and intensities of optical, gamma-ray, and neutron radiations, no adequate correlations could be made between causal factors and actual injury.

C. Nagasaki Explosion. This explosion, which took place on 9 Aug 45 at 0158 (G.C.T.), added to the information obtained from Hiroshima, particularly as regards damage to industrial buildings; but it contributed little information on pressure values, radiation intensity, or on the correlation of damage or injury data with pressure data, radiation data, etc.

Chapter 3

Organization and Preparation

Outline

Section

Chapter 3

Organization and Preparation

3.001 Introduction.

This is the history of Operation Crossroads as a technical experiment; consequently it deals principally with technical preparations and technical results.

Administrative organization and nontechnical activities are discussed only in this Chapter, and then only briefly. (They are considered in much greater detail in the "Operational History of JTF-1," prepared by Capt. A. B. Leggett Navy .)

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If the JTF-1 organization appears complicated, it is because JTF-1 consisted simultaneously of:

(1) a group of approximately 42,000 persons drawn from permanent military and civilian agencies, cooperating in one large joint scientific effort unprecedented in peacetime,

(2) a staff administering the greatest field tests ever undertaken: a technical organization, consisting of over 550 scientists and engineers, executing a $100,000,000 experiment,

(3) a force organization charged with assembling approximately 42,000 men and over 200 vessels, and more than 150 airplanes and transporting them to the middle of the Pacific Ocean and maintaining them there for several months -- all within a few months time and without endangering personnel.

These various kinds of organizations were not always distinct; the same persons often participated in several or all of these groups. The groups cooperated closely; no one group's function can be understood fully except in the light of the other groups' functions.

Before describing JTF-1 itself, we shall mention the roles played by the various government agencies and other groups from which JTF-1 was drawn.

3.002 Joint Chiefs of Staff Activities.

On 11 Jan 46 the Joint Chiefs of Staff created Joint Task Force One and placed it under the command of Vice Admiral W. H. P. Blandy. They directed the War and Navy Departments to give full support, and authorized Commander JTF-1 to deal directly with these agencies. By the same directive, they approved Admiral Blandy's recommendation that the Operation be given the code name "CROSSROADS." Besides establishing JTF-1 and designating its commander, the Joint Chiefs of Staff performed the following functions:

A. Transferring the Captured Vessels. By a directive of 18 Sept 45 to Adm. C. W. Nimitz, Chief of Naval Operations, the Joint Chiefs of Staff saved important captured Japanese vessels from routine destruction in Japanese home waters. Later, they transferred these vessels to JTF-1.

B. Channeling the Publicity. On 8 Mar 46, acting at the suggestion of the Commanding General of the Army Air Forces, the Joint Chiefs of Staff directed that all releases be made through a single channel, and that Commander JTF-1 be the channel.

C. Creating the Evaluation Board. The Joint Chiefs of Staff created the Evaluation Board to observe and evaluate the Tests.

D. Arranging Support of the Operation. The Joint Chiefs of Staff, instead of attempting themselves to provide JTF-1 with funds, personnel, and equipment, directed Commander JTF-1 to obtain administrative and logistic support directly from the War and Navy Departments. Also they authorized him to deal directly with the Manhattan Engineer District.

3.003 Navy Department Participation.

A. Pre-JTF-1 Activities. Even before JTF-1 was created 11 Jan 46 the Navy had been active in planning and preparing for atomic bomb tests against naval vessels. Thus:

1. On 28 Aug 45 Vice Adm. E. L. Cochrane, Chief of the Bureau of Ships, pointed out to his officers in charge of shipbuilding and ship design the necessity of planning experimental work to develop the effectiveness of the atomic bomb in naval warfare.

2. On 15 Oct 45 R. Adm. W. P. Purnell, Assistant Chief of Naval Operations for Material, proposed that the atomic bomb tests then under discussion be controlled by the Joint Chiefs of Staff and conducted by the Navy with the assistance of other Service groups. He proposed also that one bomb be detonated in the air and another in

water, and that besides Japanese vessels a few U. S. Naval vessels of modern design should be used in the target array.

3. On 31 Oct 45 the Secretary of the Navy authorized retention (for atomic bomb tests) of 158 surplus U. S. Naval vessels.

4. A few days prior to the formal creation of JTF-1 Vice Adm. Blandy, acting as Deputy Chief of Naval Operations, Special Weapons, submitted to the Joint Staff Planners a fairly detailed plan for conducting the atomic bomb tests.

B. General Plan for Navy Participation. On 11 Jan 46 the Chief of Naval Operations notified the principal agencies of the Navy Department that JTF-1 had been created and directed their cooperation.

Principal Navy participation in JTF-1 was by the following groups: Office of the Secretary of the Navy; Chief of Naval Operations; Commander in Chief Pacific Fleet; BuAer; BuM&S; BuOrd; BuShips; BuY&D; BuSandA; Office of Research and Inventions (now Office of Naval Research); BuPers; Marine Corps; the Hydrographic Office, and various naval ship yards. These groups are considered below:

1. Office of the Secretary of the Navy. The Office of the Secretary of the Navy assisted by (1) advising Congress as to legislation re use of certain vessels as target vessels, (2) extending invitations to various official observers, (3) providing various specialists.

The Secretary of the Navy, the Hon. James Forrestal, observed Test A. He was accompanied by his Aide, Capt. W. R. Smedberg, III, and by two special assistants, Capt. J. A. Kennedy and Capt. Frank Nash. He was berthed on the MT. MCKINLEY.

2. Chief of Naval Operations. The Office of the Chief of Naval Operations gave important support to the Operation. Before the formal creation of JTF-1, this Office played a leading part in the drawing up of the preliminary plans. It supplied many of JTF-1's ranking officers, including Commander, Deputy Task Force Commander for Technical Direction, Commander of the Advance Echelon, and Director of Ship Material (DSM). Through the principal bureaus it ordered the appropriate groups and individuals "..to temporary duty with Commander JTF-1."

The Office of the Chief of Naval Operations made available to Commander JTF-1 the necessary vessels and aircraft to form the operating naval task groups of the Task Force. Its Special Weapons Division (OP-06) devoted itself almost exclusively to the Operation.

3. Commander-in-Chief Pacific Fleet. Admiral J. H. Towers,

Commander-in-Chief Pacific Fleet and Pacific Ocean Areas, furnished a considerable fraction of the personnel required for crews of the Force Organization's vessels. Also, he furnished surface transportation for personnel, space and facilities at Pearl Harbor, and provided logistic support to the Task Force.

4. Bureau of Aeronautics. BuAer supported JTF-1 principally through the various JTF-1 ad hoc technical groups, including the DSM Aeronautics Group and the 013 (Technical Director's) Technical Photography Group. It furnished an abundance of aeronautical equipment to be exposed, and supplied drone planes for collecting radioactive air samples and conventional planes for radiological safety reconnaissance.

5. Bureau of Medicine and Surgery. BuM&S supported JTF-1 principally through the DSM Medical Group. It provided important medical personnel including the Safety Adviser and also medical materials and animals to be exposed.

6. Bureau of Ordnance. BuOrd supported JTF-1 principally through the DSM Ordnance Group and the 013 BuOrd Instrumentation Group. It provided important technical and scientific personnel, and much ordnance material to be exposed. Many BuOrd activities such as Naval Ordnance Laboratory, NOTS Inyokern, and others, furnished valuable support.

7. Bureau of Ships. BuShips supported JTF-1 principally through the DSM Ships Group, the DSM Electronics Group, and in the 013 Oceanography Group, the 013 BuShips Instrumentation Group, and the 013 Electronics Group. It supplied much equipment. It handled the very large job of conditioning the target vessels before they left for Bikini, and brought nearly all the major shipyards into the work. It made the majority of the mounts for the instruments placed on target vessels. It remodeled a number of the supporting vessels; broadcasting studios, for example, were constructed in press and observer ships; air conditioning equipment was installed in several ships; photographic laboratories were constructed on WHARTON, SAIDOR, AVERY ISLAND and KENNETH WHITING; animal pens, laboratories, and autopsy rooms were constructed in BURLESON; extensive changes were made on CUMBERLAND SOUND and ALBEMARLE.

8. The Office of Research and Inventions (ORI). This Office (now the Office of Naval Research) assisted JTF-1 through many of the Technical Director's groups and through several Director of Ship Material's groups also. Comdr. George Vaux, of the ORI Planning Division, directed the 013 Remote Measurements Group.

9. Hydrographic Office. This Office made the necessary hydrographic surveys of the Bikini Area.

10. Other Navy Groups. Other Navy groups also gave appreciable assistance. The Bureau of Yards and Docks arranged, through the DSM Ships Group, the exposing of one concrete drydock and two concrete barges and also assisted in the installation of shore facilities at Bikini. The Bureau of Supplies and Accounts arranged the exposing of a great variety of provisions, clothing, and other equipment. The U. S. Marine Corps supplied certain personnel for administrative and security duties. The Bureau of Personnel detailed the necessary naval personnel to man the target vessels and augment the complements of operating ships.

3.004 War Department Participation (except Manhattan Engineer District).

A. Pre-JTF-1 Activities. The War Department had the distinction of being the first formally to propose to the Joint Chiefs of Staff that some form of atomic bomb tests be held. On 18 Sept 45, Gen. H. H. Arnold, Commanding General of the Army Air Forces, acting 14 Sept 45 on a suggestion by Lt. Gen. B. M. Giles recommended to the Joint Chiefs of Staff that plans for the routine destruction of captured Japanese naval vessels be abandoned; and he proposed instead that a number of these vessels be made available to the AAF for use in tests involving atomic bombs and other weapons. On 31 Oct 45 he recommended that the Joint Chiefs of Staff direct the Joint Staff Planners to determine what types of tests should be made and to suggest an agency to carry out such tests.

Pre-JTF-1 activities by various groups within the Army Air Forces are included in the discussion which follows.

B. General Plan for War Department Participation. On 11 Jan 46 the Joint Chiefs of Staff notified the principal agencies of the War Department that JTF-1 had been created and requested them to cooperate. The Adjutant General, acting on 28 Jan 46 with the approval of the Secretary of War, issued a directive to the Commanding Generals of the Army, Air, Ground, and Service Forces to give JTF-1 full cooperation and to direct all subordinate agencies to furnish all practicable support and assistance requested by the Commander JTF-1.

The Army Ground Forces assisted JTF-1 staff principally through the services of Maj. Gen. A. C. McAuliffe (JTF-1 Ground Forces Adviser). It provided considerable personnel and equipment, particularly to the JTF-1 Army Ground Group (Task Group 1.4).

The Army Technical Services provided personnel and equipment, particularly to the JTF-1 Army Ground Group (Task Group 1.4) and to the DSM Army Group.

The Army Air Forces supported the JTF-1 staff principally by supplying the services of Maj. Gen. W. E. Kepner who was designated Deputy Task Force Commander for Aviation and the majority of the personnel for the Air Staff. Discussed below is the participation in JTF-1 by the following groups of the Army Air Forces: Office of Assistant Secretary of War for Air, Office of the Chief of Army Air Forces, Headquarters Army Air Forces, Air Material Command, Air Transport Command, and Headquarters Strategic Air Forces.

1. Office of Assistant Secretary of War for Air. The Office of the Assistant Secretary of War for Air assisted by (1) monitoring the AAF operations and insured prompt necessary action by AAF to implement the requirements of JTF-1, (2) extending invitations to various prominent national aviation officials to view the Tests as Air Forces observers, and (3) providing various specialists.

The Assistant Secretary of War for Air, Mr. Stuart Symington, observed Test A from the air. He was accompanied by Mr. Robert Hannegan, Postmaster General of the U. S.

2. Office of the Chief of the Army Air Forces. The Office of the Chief of the Army Air Forces gave important support to the Operation. Before the formal creation of JTF-1 this office played a large part in drawing up the preliminary plans. It supplied the Deputy Task Force Commander for Aviation and an Assistant Deputy Task Force Commander for Aviation. It ordered the principal Staff Division of AAF and the principal Commands of AAF to support the Operation on the highest priority.

3. Headquarters Army Air Forces. Headquarters Army Air Forces established a project office under the Assistant Chief of Air Staff-3, which was responsible for the entire Army Air Forces' participation in the Operation before JTF-1 was officially established. All staff sections coordinated to provide personnel and aircraft, to modify aircraft, to provide air transportation, to train Army Air Forces units, and to place these units in operational condition and position at the required time. In addition it provided personnel and equipment for the 013 AAF Electronics Group.

4. Air Material Command. The Air Material Command supported the Operation by providing the B-17 drone planes for Task Unit 1.5.6, technical specialists, and by modifying AAF aircraft to meet the exacting demands of this technical operation. It provided special camera equipment, photographic and scientific personnel; also it provided Air Forces equipment to be exposed.

5. Air Transport Command. The Air Transport Command was augmented in personnel and equipment to the extent that twenty C-54's were operated between Kwajalein and San Francisco in addition to

regular ATC aircraft to provide adequate air lift of personnel and supplies to and from the test area.

6. Headquarters Strategic Air Forces. Headquarters Strategic Air Forces (formally Continental Air Forces) provided the majority of the personnel required for Task Group 1.5, (Army Air Group). This Headquarters was charged by Headquarters Army Air Forces with equipping and training the Army Air Group within the Continental U. S.

3.005 Manhattan Engineer District Participation.

(In this History, the term Manhattan Engineer District is used synonymously with the term, Manhattan Project, the latter being the over-all agency concerned with atomic bomb production.)

The Manhattan Engineer District, the group which has made all the atomic bombs produced to date, operated throughout the Operation with relative independence. For that reason, it is discussed here separately from the discussion of the other Army Groups.

A. Pre-JTF-1 Activities. The Manhattan Engineer District assisted the early planning of the Operation as follows:

1. It made available to the Deputy Task Force Commander for Technical Direction the results of studies it had made on underwater explosions. Some of these had been based on scale tests (the so-called "Seal" tests) carried out during the war by New Zealand scientists; others were based on model tests carried out by various U. S. Army and Navy groups. Some of the studies -- those made in 1944 -- had been directed towards planning an atomic bomb attack on Japanese Fleet units at Truk Island. (For obvious reasons this plan was later abandoned.) Results of all these studies were of especially great assistance in planning Test B, the underwater explosion.

2. It presented the first detailed technical plan as to how the bombs might best be delivered, detonated, and appraised. This plan, known as the "Williams Plan," played a central part in many of the earlier discussions, including important discussions held on 19, 20, and 21 Dec 45.

3. Through Maj. Gen. L. R. Groves, Commanding General of the Manhattan Engineer Project, Dr. N. E. Bradbury, Director of the Los Alamos Laboratory, and other representatives, it contributed valuable advice in the principal conferences, including conferences attended by the Military Advisory Board to the Officer-in-Charge of the Atomic Bomb Project.*

B. Activities After Creation of JTF-1. After the formal creation of JTF-1, the Manhattan Engineer District assisted JTF-1 principally through the 013 Los Alamos Group and the 013 Radioactivity Group. Also it supplied various key personnel, including Dr. R. A. Sawyer (013), Technical Director.

The Manhattan Engineer District selected 27 observers for Test A and 20 for Test B. (These men are listed in Section 3.009.)

3.006 Participation by Other Government Agencies.

Various other agencies of the Government assisted in the Operation. The principal ones are discussed here.

A. Department of the Interior.

1. Fish and Wildlife Service. On 21 Nov 45 the Secretary of the Interior suggested that the Department of the Interior help in the selection of a test site which would offer minimum damage to our fishery resources. This suggestion was acted on by the Secretary of the Navy, who invited the Department of the Interior to designate

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* The Military Advisory Board to the Officer-in-Charge of the Atomic Bomb Project was created on 26 Oct 45 to help coordinate and integrate the activities of the War and Navy Departments with the activities of the Manhattan Engineer District. Its membership comprised: Maj. Gen. (now Gen.) C. E. LeMay; Brig. Gen. (now ret. Col.) W. A. Borden; Brig. Gen. G. A. Lincoln; Brig. Gen. Hobart Hewett; Col. H. W. Mansfield; R. Adm. (now Vice Adm.) W. H. P. Blandy; R. Adm. W. R. Purnell; R. Adm. (now Vice Adm.) G. F. Hussey, Jr.; R. Adm. H. G. Bowen; also Maj. Gen. L. R. Groves, Officer-in-Charge of the Atomic Bomb Project. Lt. Col. J. A. Derry was Acting Secretary. On 20 Nov 45 Commo. (now R. Adm.) W. S. Parsons was designated alternate for R. Adm. W. R. Purnell. It held important meetings on 29 Jan 46 and 19 Feb 46.

representatives for this purpose. On 21 Dec 45 Dr. I. N. Gabrielson, then Director of the Fish and Wildlife Service of the Department of the Interior, appointed its chief fishery biologist, Mr. Elmer Higgins, as liaison officer with JTF-1.

The Fish and Wildlife Service designated a group of three scientists to assist JTF-1 in the carrying out of fish surveys at Bikini. The group comprised Dr. V. C. Brock, loaned by the Territory of Hawaii and placed in immediate charge of the field work, Dr. L. P. Schultz, Curator of Fishes at the U. S. National Museum, and Mr. J. C. Marr, Biologist of the Fish and Wildlife Service's Pacific Coast staff. (Capt. E. F. Herald [Army] on 6 June 46 was assigned to take Dr. Schultz's place in this group.)

2. Geological Survey. The Department of the Interior furnished additional assistance (requested by Commander JTF-1 on 8 Mar 46) through its Geological Survey, directed by Dr. W. E. Wrather.

Working in cooperation with the 013 Oceanography Group, the Geological Survey undertook to investigate the physiography and geology of the islands of Bikini Atoll, the shore and beach processes, and the ecology of coral reefs.

B. Smithsonian Institution. The Smithsonian Institution cooperated with the 013 Oceanography Group by studying the biological and oceanographic phenomena of the Bikini region.

The National Museum of the Smithsonian Institution also provided assistance, as through the services of Dr. L. P. Schultz, Curator of Fishes, in making fish surveys and also studies of littoral and land animals, reef and lagoon fish, algae, seed plants, plankton of the Lagoon and open sea.

C. Federal Security Agency. The National Cancer Institute of the Federal Security Agency helped the DSM Medical Group by providing 120 mice, some of especially high predilection to cancer and some of especially low predilection. It was thought that the radiations from the explosions might produce interesting results.

The National Institute of Health of the U. S. Public Health Service also assisted the DSM Medical Group. (See Chap. 8.) Other personnel from the U. S. Public Health Service were loaned to the 013 Radioactivity Group.

D. Department of Commerce. The Department of Commerce's National Bureau of Standards assisted the 013 Remote Measurements Group in its attempts to detect the explosion from remote locations.

The Coast and Geodetic Survey of the Department of Commerce supported the 013 Oceanography Group by investigating tides and also strong-motion seismic disturbances caused by the explosions.

E. Department of Agriculture. The Department of Agriculture assisted the DSM Medical Group by supplying samples of seed, grain, and insects for exposure to the radiations from the explosions. It was thought that interesting mutations might result.

F. State Department. The State Department played a part in August and September of 1945 in determining policy as to availability of Japanese and German vessels as targets.

The State Department was the agency which extended to certain foreign countries invitations to send observers to the Tests.

G. Treasury Department. The U. S. Coast Guard of the Treasury Department furnished ships and personnel. It offered the services of Lt. Comdr. C. A. Barnes as technical assistant in charge of the oceanographic survey work. Two Coast Guard vessels operated at Bikini, the REDBUD engaged in laying navigational buoys at Bikini, and the BRAMBLE assisted in a brief survey of the western islands of Bikini Atoll. These vessels operated as a part of the Force Organization under the Survey Unit (Task Group 1.8).

3.007 Participations by Other Groups and Individuals.

Besides the military and nonmilitary federal agencies participating in the Operation, there were also many additional (foreign and domestic) groups and individuals participating. Their organizations and activities are described briefly in this Section.

A. Participation by Industrial Concerns. Among the industrial concerns participating in the Operation -- either directly or through supplying personnel and equipment -- were the following:

- Bell Telephone Laboratories, New York, N. Y.
- Eastman Kodak Co., Rochester, N. Y. (films, cameras, and film processing)
- Fairchild Camera and Instrument Co., Jamaica, N. Y. (engineering services, and design and building of special "log interval timer" devices)
- Geotechnical Corp., Dallas, Texas (seismic measurements)
- Polaroid Co., Cambridge, Mass. (high-attenuation goggles)
- Raytheon Manufacturing Co., Waltham, Mass. (engineering services for sonar and radar electronic equipment)

RCA, Camden, N. J. (engineering services and telemetering instrumentation)
Submarine Signal Co., Boston, Mass.
Victoreen Instrument Co., Cleveland, O. (radioactivity instruments)
Western Electric Co., N. Y.
Westinghouse Manufacturing Co., Pa.

B. Participation by Universities and Institutions. Among the universities and institutions participating in the Operation -- directly or indirectly -- were the following:

Cornell University (engineering services and telemetering equipment)
Franklin Institute's Bartol Foundation (detecting remote radioactivity)
Harvard University (detecting changes in the ionosphere)
Montana State College (remote detection measurements)
Princeton University (engineering services and telemetering equipment)
South Dakota State School of Mines (remote detection measurements)
Stanford University (detecting changes in the ionosphere)
University of California, including the Scripps Institution of Oceanography (services of technical personnel)
University of Chicago (remote detection measurements)
University of Louisiana (detecting changes in ionosphere)
University of Rochester (radioactivity, optics)
University of Washington (pressure measurements)
Woods Hole Oceanographic Institution (seismographic disturbances)

C. Participation by British Scientists. In response to a request of 12 Nov 45 by the British Admiralty Delegation to the effect that a small group of British scientists be permitted to participate in the planning and execution of the tests, the Joint Chiefs of Staff decided on 5 Dec 45 that participation by British scientists would be welcome.

Most prominent among the British scientists and engineers participating was Dr. W. G. Penney, who was Consultant to the Theoretical Physics Division of the Los Alamos Laboratory. A total of nine British scientists participated: blast-pressure phenomena were studied by Dr. W. G. Penney, Dr. J. H. Powell, and Dr. R. Pilgrim and Lt. Comdr. R. J. Daniel; physiological effects were investigated by Dr. F. C. MacIntosh and Dr. E. E. Pochin; assistance was given in radiation measurements work by Mr. J. L. Tuck. Dr. E. W. Titterton was concerned with electronics equipment. Dr. G. I. Taylor, acted as a scientific consultant during the early planning stage.

D. Participation by Civilians. More than 500 civilian scientists and engineers took part in the Operation. They were drawn from nearly all major branches of science and engineering, and collectively they were well fitted to the particular task at hand: carrying out elaborately instrumented scientific and engineering tests of atomic bombs.

3.008 Press Groups.

A. Size of Groups. The Joint Chiefs of Staff's recommendations of 10 Jan 46, setting forth proposed quotas for press representatives, were approved by the Secretaries of War and Navy 5 Feb 46 and by the President 14 Mar 46. As shown in the following table, the numbers actually attending were less than the quotas approved:

	Quota	Actual Attendance	
		Test A	Test B
Representatives of U. S. press, radio, pictorial services, magazines, etc.	200	114	75
Foreign press, one representative from each nation having membership in UN Atomic Energy Commission, plus two extra representatives from Great Britain	13	10	8

B. Domestic Press, Radio, and Pictorial Group.

1. Introduction. The domestic press, radio, and pictorial group included representatives from widely known news agencies as well as relatively unimportant newspapers and magazines.

Most of the correspondents went by sea and thus had an opportunity for proper orientation.

The majority of the representatives were transported by APPALACHIAN, the JTF-1 press headquarters ship; some were transported by air. In the Marshall Islands the majority of the representatives were berthed on APPALACHIAN: others were berthed on MT. McKINLEY (flagship), PANAMINT (observer ship), SAIDOR (photographic headquarters ship), and at Kwajalein where a Press Branch Headquarters was located. Precedence in berthing accommodations and other nonprofessional privileges was established by the age of the correspondents, the oldest being most privileged.

2. Security. Security planning proceeded from the decision that there would be no censorship or review except re photographs. Security was insured by limiting the places to which the representatives had access. Because pictorial representatives were given especially broad access, all their film was developed and screened before release.

3. Facilities Available. The representatives were provided with extensive facilities for transmitting information to the United States through voice radio, radio teletype, radio photo and air-mail.

News coverage statistics for both Tests are as follows:

Press wordage transmitted by radioteletype	2,900,000
Commercial radio broadcast transmissions	750
Photographs transmitted by radio-photograph	500

C. Foreign Press. In accordance with the Joint Chiefs of Staff's recommendations one press representative was invited from each of the nations represented on the Atomic Energy Commission of the United Nations Security Council. Two additional British representatives were invited in recognition of the special assistance given by that nation in developing the atomic bomb. Invitations to the foreign press were transmitted by the State Department to the foreign offices of the eleven governments concerned; three of these did not send representatives to cover Test A; five sent no representatives to cover Test B.

Difficulty was experienced in deciding what priority the foreign press representatives should have in transmission of dispatches. Actually, each foreign press representative was treated as representing a "news service" of his country, rather than as representing an individual newspaper. This policy gave the foreign press representatives privileges somewhat superior to those enjoyed by representatives of individual U. S. newspapers, but not equal to those enjoyed by U. S. news services.

D. Effectiveness of Groups. The domestic and foreign press groups were generally successful in telling the people of the world the story of the objectives, planning, and execution of the Operation. The public learned that the Operation was fairly and capably managed, and successfully executed. The capabilities of atomic bombs used against Naval vessels were pictured promptly. The atomic bomb was taken out of the realm of the fantastic and incomprehensible in the public mind and placed approximately in its proper light as a real and very powerful weapon.

3.009 Observer Groups.

A. Introduction. A large number of military and civilian, scientific and lay, foreign and domestic observer groups witnessed the Tests. In accordance with the Joint Chiefs of Staff's action on 10 Jan 46 (See Sec. 3.008), the quota listed below was established:

Observer Group	Quota	Actual Attendance Test A	Actual Attendance Test B
Members of Congress			
House	30	7	4
Senate	30	2	0
U. S. Services			
Army)	116	61	55
Navy)		26	14
U. S. Civilian Scientists	30	22	19
Foreign nations having membership on UN Atomic Energy Commission, 2 per Nation	22	21	21
Additional British Observers	8	9	9
Additional Canadian Observers	4	4	4
Total	240	152	126

B. Congressional Observer Group. On 14 June 46 the Secretaries of War and Navy addressed letters to the President, Pro Tempore, of the Senate, the Honorable Kenneth McKellar, suggesting that he nominate ten senators to observe the Tests. Corresponding letters were sent to the Speaker of the House, the Honorable Sam Rayburn. Commander JTF-1 issued formal invitations.

The following Congressmen witnessed the Tests:

Senators	Congressional Observers who attended Test A	Congressional Observers who attended Test B
Cordon, Guy, Oregon	x	
Hickenlooper, B. B. Iowa	x	
Hatch, C. A., New Mexico	x	x
Saltonstall, Leverett, Mass.	x	x
Representatives		
Anderson, J. Z., California	x	x
Andrews, W. G., New York	x	
Bates, G. J., Massachusetts	x	
Bradley, M. J., Pennsylvania	x	
Engel, A. J., Michigan		x
Gillespie, Dean M., Colorado	x	x
Holifield, C., California	x	x
Izac, E. V., California	x	x
Norrell, W. F., Arkansas	x	
Rooney, J. J., New York	x	

The Congressional observers flew to Kwajalein and were berthed on PANAMINT.

C. The Joint Chiefs of Staff's Evaluation Board. This group is discussed in Sec. 1.005.

D. President's Evaluation Commission. This group is discussed in Sec. 1.006.

E. U. S. Service Observer Groups. The Joint Chiefs of Staff selected the members of the U. S. Service Observer Group. For Test A there were 61 Army observers, (including 15 from the Army Air Forces), and 26 Navy observers. Most of them left Washington by a special Crossroads train and boarded BLUE RIDGE at Oakland, California. The BLUE RIDGE berthed the military personnel during the Tests.

F. Manhattan Engineer District Representatives. The Manhattan Engineer District invited a number of representatives as their guests to witness the Tests. These included Manhattan Engineer District personnel, and others who had played a role in the research and development of the bomb and who had returned to their normal peacetime pursuits. This group went by airplane to Kwajalein, from thence by destroyer to Bikini where they were berthed on CUMBERLAND SOUND. The members of the group are listed below:

Test A	Test B
Baker, A. L., Mr.	Antes, D. E., Col.
Benedict, Manson, Dr.	Bagley, Glen D., Mr.
Booth, E. T., Dr.	Chipman, John, Dr.
Brown, Edwin H., Mr.	Clarke, F. J., Lt. Col.
Coolidge, W. D., Dr.	Fernelius, W. C., Dr.
Currie, L. M., Dr.	Fields, K. E., Col.
Dunning, J. R., Dr.	Free, R. H., Lt. Col.
Gee, H. C., Col.	Hutcheson, J. A., Dr.
Hageman, R. C., Mr.	Klein, A. C., Mr.
Hasbrouck, S. V., Col.	LaCrosse, Emmart, Mr.
Haywood, O. G., Jr., Col.	Lavender, R. A., Capt (USNR)
Hinds, J. H., Col.	Long, Kenneth, Mr.
Hochwalt, C. A., Dr.	Lum, J. H., Dr.
Hull, D. E., Dr.	MacNeill, J. B., Mr.
Jannarone, J. R., Lt. Col.	Marsden, C. H., Col.
Jones, Edwin L., Mr.	Nagler, Forrest, Mr.
Keirn, D. J., Col.	Nichols, K. D., Col.
Kelley, W. E., Lt. Col.	Roper, H. McK., Col.
Kelly, E. B., Lt. Col.	Stevens, W. A., Lt. Col.
Klaussen, Bjarne, Mr.	Stewart, S. L., Lt. Col.
Krueger, P. G., Major	Urey, Harold, C., Dr.
Murphy, E. J., Dr.	
Nichols, K. D., Col.	
Robertson, A. W., Dr.	
Sheahan, R. D., Mr.	
Spedding, F. H., Dr.	
Travis, J. E., Major	

G. Members of Civilian Scientific Observer Group. Acting 6 Mar 46 on an invitation from Vice Adm. Blandy, Dr. F. B. Jewett, President of the National Academy of Sciences, nominated certain civilian scientists to attend the Tests. Thirty-two invitations were issued by Vice Adm. Blandy, and these twenty-two men accepted:

Akin, Dr. R. N.	Lorraine, Mr. R. G.
Atkinson, Mr. Ralph	Pratt, Mr. Haraden
Bousman, Mr. H. W.	Rubey, Mr. W. W.
Campbell, Mr. C. I.	Skilling, Dr. H. H.
Darling, Dr. G. B.	Starr, Mr. E. C.
DeMent, Mr. Jack	Stevens, Mr. H. N.
Dunbar, Dr. C. O.	Trask, Dr. P. D.
Galtsoff, Dr. P. S.	VanDyck, Mr. A. F.
Grebe, Dr. J. J.	Vickery, Dr. H. B.
Kirkbride, Mr. C. G.	Wilson, Mr. W. M.
Kirkpatrick, Mr. S. D.	Yoe, Mr. J. H.

All of these men attended Test A, and all except Mr. C. I. Campbell, Dr. G. B. Darling, and Mr. Haraden Pratt attended Test B.

H. United Nations Observer Group. A desire to invite United Nations representatives was expressed by the Services and by large sections of the public even before the Task Force was formally created. The Joint Chiefs of Staff considered the matter as early as 10 Jan 46. The definitive (favorable) decision was made by the State Department -- which on 5 Feb 46 forwarded its decision to the State-War-and-Navy Coordinating Committee. President Truman indicated his approval of the decision on 14 Mar 46.

The Secretary of State accordingly requested the U. S. ambassadors or ministers in the eleven foreign countries having membership in the United Nations Atomic Energy Commission to invite those countries to choose their official representatives. The countries and their representatives were:

Australia:	Commander S. H. K. Spurgeon, R. A. N.
Brazil:	Major Orlando Rengel (Army) Captain Alvaro Alberto de Motta y Silva (Navy)
Canada:	Air Vice Marshal E. W. Stedman Major General R. M. Luton, (Retired)
China:	Chung-Yao Chao, Director of the Department of Physics, National Central University Major General Fisher Hou, Military Attache, Washington, D. C.
France:	Captain de Fregate Pierre Balande, General Staff (Navy) Mr. Bertrand Goldschmidt
Egypt:	Colonel Hassan Rajab, Military Attache, Washington, D. C. Lieutenant Colonel Abdel-Gaffar Osman, Chief Inspector of Explosives (Army)
Great Britain:	Flight Lieutenant F. Beswick, M. P., R. A. F. Commander A. H. P. Noble, M. P., R. N.
Mexico:	Mr. Juan Loyo Gonzalez Dr. Nabor Carillo
Netherlands:	Captain G. B. Salm, Head of Naval Intelligence Major H. Bruining, Minister of Supply

Poland:	Mr. Stefan Pienkowski, Pres., University of Warsaw Mr. Anrzej Soltan, Head of Physics Department, University of Lodz
U. S. S. R.:	Dr. A. M. Mescheryakov, Head Physics Department, University of Leningrad Mr. S. P. Alexandrov

The majority of these representatives assembled in Washington, D. C., and went by special train to Oakland, California. There they boarded PANAMINT, reaching Bikini 30 June 46 (G.C.T.).

The United Nations observers were given the same access that the U. S. press representatives had to written records and to the target vessels.

The United Nations observers remained for both Tests, making a tour of the neighboring islands during the interval between the Tests.

They returned to the United States after the Tests, and later wrote Vice Adm. Blandy expressing their thanks for having been invited and their appreciation of the courteous treatment they received.

I. British Observer Group. Besides the British representatives who assisted in the planning and execution of the Tests (see Sec. 3.007) and the British United Nations Observers, 13 other representatives of the British Empire were invited through the British Government. Four Canadians, 8 Englishmen, and 1 Australian attended both Tests. The majority of these men were officers in the British Navy and Royal Air Force, but two civilians were included also.

3.010 General Organization of Staff.

There were four general aspects of the Crossroads organization -- staff organization, technical organization, force organization, and temporary ad hoc league of permanent Army, Navy, and civilian groups. The staff organization will be described first.

Fig. 3.1 shows the JTF-1 staff organization. It was established almost immediately after the designation of the Task Force Commander and in the main followed the usual pattern of Naval and Army staff organization. However, it was carefully arranged to provide maximum freedom for the technical groups and to insure full cooperation from the many military and civilian agencies participating. It is to be noted that no chain of command existed between JTF-1 and either the Evaluation Board, the President's Evaluation Commission, or the Man-

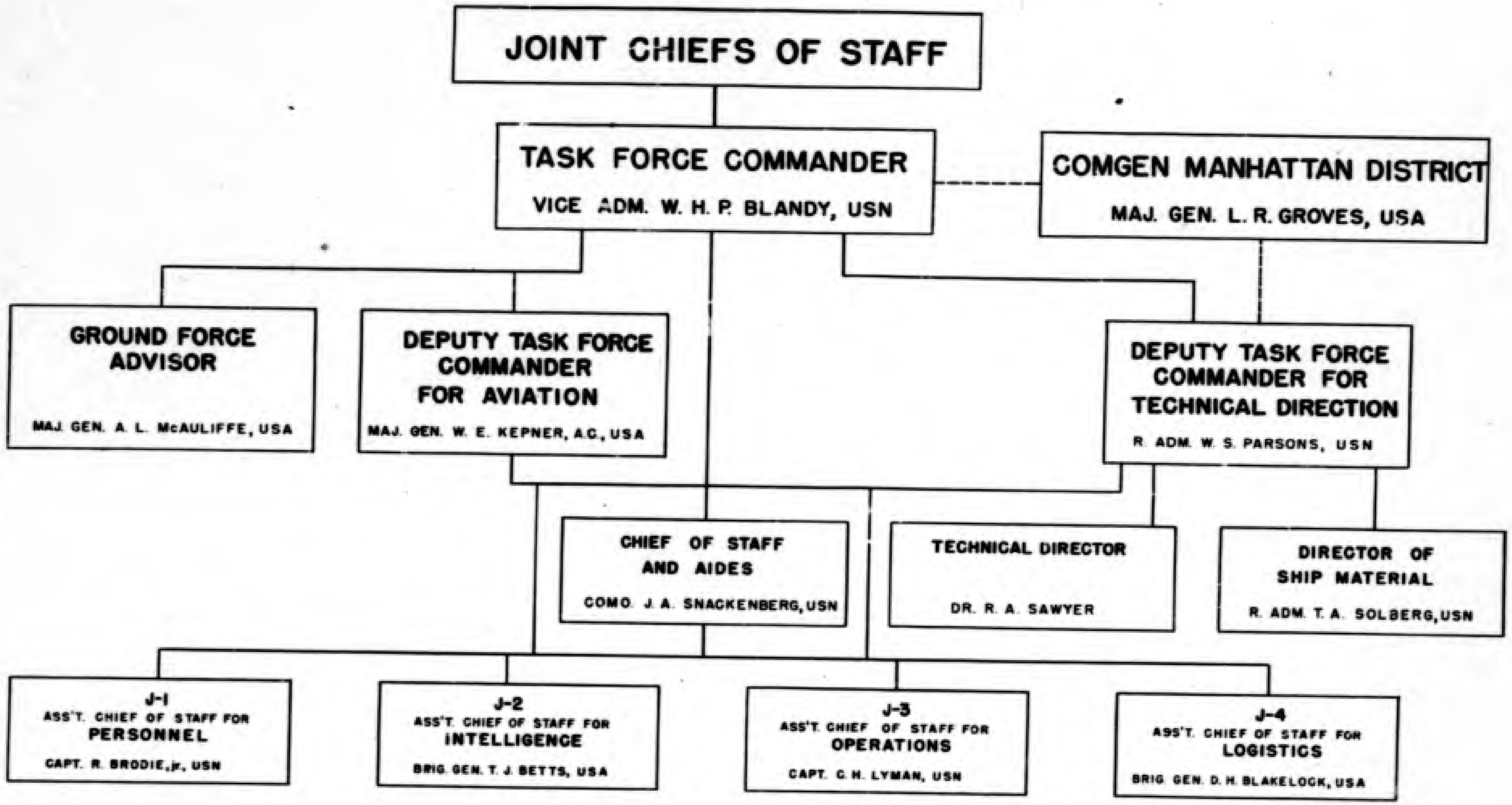

FIG. 3.1 STAFF ORGANIZATION OF JTF-1

hattan Engineer District -- although adequate liaison existed in each case.

Instructions defining responsibilities of each upper-echelon official in the organization were promulgated formally on 2 Mar 46.

We shall discuss separately in the following sections: Commander, Deputy Task Force Commander for Technical Direction, Deputy Task Force Commander for Aviation, Ground Forces Adviser, Chief of Staff, and each of the Assistant Chiefs of Staff.

3.011 Commander (00).

A. Designation. On 11 Jan 46 the Joint Chiefs of Staff, acting with the approval of the President, confirmed the designation of Vice Adm. W. H. P. Blandy as Commander (Code 00). Although the Army Air Forces member of the LeMay Subcommittee of the Joint Staff Planners had proposed on 14 Dec 45 that Maj. Gen. L. R. Groves be made Commander, the Joint Chiefs of Staff decided that, since the great majority of personnel, ships, and material would be drawn from Navy, the commander should be a Naval officer. The naming of Vice Adm. Blandy as Commander was proposed on 15 Dec 45 by Commo. (now R. Adm.) W. S. Parsons, senior Navy member of the LeMay Subcommittee.

Vice Adm. Blandy was a logical choice for Commander of JTF-1 in view of his previous experience in commanding destroyer groups, cruiser groups, and amphibious groups, and in view of his position (since November 1945) as Deputy Chief of Naval Operations, Special Weapons (OP-06). (This Special Weapons group had been recently created by Congress to coordinate Naval development of atomic energy and guided missiles.)

B. Responsibility. The responsibility of Commander JTF-1 extended to all phases of the Operation, including organization, Force Organization plans, technical plans, execution of plans, safety, security, public relations, and preparation of full technical and operational reports.

Actually, the Commander of JTF-1 delegated the discharge of the majority of his responsibilities to his principal assistants, including especially the Deputy Task Force Commander for Technical Direction, the Deputy Task Force Commander for Aviation, the Ground Forces adviser, and the Chief of Staff. He delegated the discharge of his JTF-1 rear echelon responsibilities to a Rear Echelon Commander to act during his absence from Washington, D. C.

C. Activities. Before he left Washington, D. C., for Bikini, Commander JTF-1 devoted the majority of his time to making decisions on major policy issues, conferring with the Joint Chiefs of Staff, Congressional committees, the Evaluation Board, and the President's Evaluation Commission; also to studying and approving the Operation Plan.

He selected Rear Adm. F. J. Lowry as Commander of the Rear Echelon, and gave him charge of JTF-1 activities in the United States during the absence of Commander JTF-1 from Washington.

On 15 May 46 the Commander JTF-1 hoisted his flag on the MT MCKINLEY and assumed tactical command of the forward echelon of JTF-1. At Bikini he made many inspection trips to other vessels, to land installations on Bikini Atoll and to neighboring atolls.

The day preceding Test A, he announced the time at which the first explosion was intended to take place (How Hour) and issued final instructions and precautionary warnings. Following Test A, he made a brief announcement as to the execution and results. Later, he indicated the time when re-entry of the target area would be permitted. Still later he issued further statements as to the damage.

He performed similar functions for Test B.

On 10 Aug 46 he left Bikini on the MT MCKINLEY, arriving in Pearl Harbor 16 Aug 46. On 19 Aug 46 he hauled down his flag from the MT MCKINLEY and returned by air to Washington, D. C., arriving there on 20 Aug 46. He then made preliminary informal reports to the Joint Chiefs of Staff, and to other evaluation groups. He expedited the preparation of technical reports.

3.012 Deputy Task Force Commander for Technical Direction (01).

A. Designation. On 26 Feb 46 Rear Admiral W. S. Parsons was formally designated (by Commander JTF-1) Deputy Task Force Commander for Technical Direction (Code 01). He had served over two years at the Los Alamos Laboratory, where he was head of the Ordnance Division, and he had supervised the combat delivery of the atomic bombs dropped on Japan.

B. Responsibility. The responsibility of the Deputy Task Force Commander for Technical Direction was to plan, organize, and (through the Chief of Staff, the Technical Director, and the Director of Ship Material) direct all technical activities of the Operation.

In addition, he served as liaison officer between JTF-1 as a whole, and the Manhattan Engineer District as a whole.

C. Technical Staff Organization. The technical staff of the Deputy Task Force Commander for Technical Direction included: (a) four immediate assistants: Dr. John von Neumann (Scientific Adviser), Capt. F. L. Ashworth (Navy) (Assistant for Aviation), Capt. Horacio Rivero (Navy) (Assistant for Special Projects) and Dr. W. A. Shurcliff (Technical Historian); (b) two technical administrators: Dr. R. A. Sawyer (Technical Director; code 013), and R. Adm. T. A. Solberg (Director of Ship Material; code 014); (c) two technical advisers: Capt. G. M. Lyon (Navy) (SafetyAdviser; code 015) and Col. S. L. Warren (Radiological Safety Adviser; code 016). The technical administrators and technical advisers are discussed in later sections.

D. Activities. Rear Admiral Parsons gave most of his time to supervision of technical activities. These involved bomb and target vessel preparation; inspection trips to review instrumentation and damage on target vessels and installations ashore; making decisions on major technical problems, and rendering reports of technical matters to Commander JTF-1. In his dual capacity of Deputy Task Force Commander for Technical Direction and Commander of Task Group 1.1 (Technical Group) he was able to coordinate the technical and operational features of the Tests.

He made several visits to Kwajalein to inspect bomb preparations. The night before Test B he and two 013 Los Alamos Group scientists remained aboard the Zeropoint ship, LSM-60. On B-Day morning he and his companions made final inspection of that ship, and left her (2 hr and 27 min before How Hour) after all other groups had evacuated the target area.

He was berthed on ALBEMARLE, and also on MT MCKINLEY.

He returned by air to Washington, D. C., arriving there on 20 Aug 46.

3.013 Deputy Task Force Commander for Aviation (02).

A. Designation. On 7 Jan 46 Major General W. E. Kepner was nominated by the Commanding General of the Army Air Forces for the position of Deputy Task Force Commander for Aviation (Code 02).

B. Responsibility. The Deputy Task Force Commander for Aviation was responsible for planning, organizing, and (through the Chief of Staff) directing all aviation activity. This responsibility extended, of course, to air transport of personnel and equipment, preparation of base facilities for air operations, delivery of Bomb A, air planes for A-Day and B-Day; it included activities of Army and Navy planes; conventional planes, drone planes, and helicopters;

planes for technical and nontechnical purposes. (However, it did not extend to the damage-to-aircraft program, which was directed by the Director of Ship Material on behalf of the Deputy Task Force Commander for Technical Direction.)

C. Staff Organization. In his duties as Deputy Task Force Commander for Aviation, Maj. Gen. Kepner was assisted by a staff of approximately 12 persons. Principal among these were: Brig. Gen. T. S. Power (Assistant Deputy Task Force Commander for Aviation), and Capt. H. D. Riley (Navy) (Assistant for Naval Aviation).

The Deputy Task Force Commander for Aviation worked closely with other organizations concerned with air activities, including especially: Assistant Chief of Staff for Operations, Assistant Chief of Staff for Logistics. He directed the activities of the Army Air Group (Task Group 1.5), and Navy Air Group (Task Group 1.6). (These organizations are discussed in later sections.)

D. Activity. After his arrival in Washington on 17 Jan 46, Maj. Gen. Kepner took a leading part in the planning of the air activities of the Operation. He guided the preparation of the Air Plan. He initiated the training of crews for the Bomb-A drop. He helped work out air lift plans, including the Green Hornet Airline between Washington, D. C., and Albuquerque, N. M.

Major General Kepner flew to Pearl Harbor where, on 22 Apr 46, he boarded MT MCKINLEY. He attended many conferences and made many inspection tours of Bikini and Kwajalein activities. He viewed both explosions from the MT MCKINLEY.

He returned to Washington, D. C. on 13 Aug 46.

He initiated an investigation as to the causes of the abnormal position of the Bomb-A detonation point which was outside the limit-of-error circle based on the results achieved in the many practice drops.

3.014 Ground Forces Adviser (03).

A. Designation. Major General A. C. McAuliffe was designated Ground Forces Adviser on 14 Jan 46. He had been Commanding Officer of the 101st Airborne Division of the Army Ground Forces.

B. Responsibility. The Ground Forces Adviser was responsible for advising Commander JTF-1 on the planning, organizing, and directing of all activities of the Army Ground Forces' participation, including the exposure (to the atomic bombs) of Army equipment. (See

Sec. 3.028 regarding activities of the Army Ground Group.)

C. Staff Organization. The Ground Forces Adviser's staff was small. The detailed work of planning and executing the Army Ground Forces program was carried out by the DSM Army Group (Section 3.021) which was essentially identical to the Army Ground Group (Task Group 1.4) (See Sec. 3.028).

D. Activities. At Bikini, Maj. Gen. McAuliffe was berthed on the MT MCKINLEY. He participated in staff conferences and made several tours of inspection of Army equipment.

3.015 Chief of Staff (J-0).

Commodore J. A. Snackenberg was formally designated Chief of Staff (J-0) of JTF-1 on 14 Mar 46. He assisted and advised the Commander JTF-1 in matters of organization and administration, and he coordinated all staff activities and issued the general orders required for carrying out the broad policies of JTF-1. He was assisted by four assistant chiefs of staff, two from the Army and two from the Navy. Their duties are discussed briefly in the four following sections.

Fig. 3.1 (in Sec. 3.010) shows the staff organization.

3.016 Assistant Chief of Staff for Personnel (J-1).

Captain Robert Brodie, Jr., (Navy) was designated Assistant Chief of Staff for Personnel (J-1) on 6 Mar 46. He was responsible for the procurement of personnel, for advising on all matters pertaining to personnel, and for arranging (with the help of the Assistant Chief of Staff for Logistics) the transportation, quartering, messing, recreation, and welfare of all JTF-1 personnel.

Fig. 3.2 shows the organization of the Personnel Division.

3.017 Assistant Chief of Staff for Intelligence (J-2).

Brigadier General (now Col.) T. J. Betts was designated Assistant Chief of Staff for Intelligence (J-2) on 9 Jan 46. His responsibility included maintaining good public relations and security.

Fig. 3.3 shows his staff organization. Each of the four major divisions is described separately below:

A. Public Information Section (J-21). Captain Fitzhugh Lee (Navy), was Head of the Public Information Division (J-21) was responsible for issuance of official releases to the public and for control of the press, pictorial, and radio representatives.

Official releases took the form of mimeographed statements by Commander JTF-1, by Deputy Commanders, by officers of the Public Information Division, and statements made orally by JTF-1 officials at press conferences. Over sixty-five mimeographed releases, 20,000 still photographs, and several short motion-picture films were issued during the Operation, and over a score of press conferences were held -- principally on APPALACHIAN and in Washington, D. C.

The handling of press, pictorial, and radio representatives raised a number of interesting problems. Several of these are discussed below:

1. Whether to Invite Press and Radio Representatives. Despite the obvious difficulties which would result from inviting press and radio representatives to observe what was (in many technical phases) essentially a secret operation, the decision was made by the Joint Chiefs of Staff to invite such representatives in order (a) to help keep the public as fully informed as security requirements permitted, and (b) to help forestall any subsequent inference by the public that the Operation might not have been conducted along worthwhile, forward-looking lines for the impartial development of national defense.

2. Which Press, Pictorial, and Radio Representatives to Invite. The question immediately arose -- once it had been decided to invite press and radio representatives -- whether to have the government select the representatives to be invited or to ask the press to make the selection. The latter alternative was chosen.

The list of publicity media to be represented was thus drawn up (with the direct cooperation and participation of a Civilian Press Committee) from the wide variety of commercial agencies, which applied for permission to send representatives. A general attempt was made to secure wide geographic coverage, to permit representation by a large number of independent newspapers and magazines, and, of course, to permit representation by the large news services, pictorial services, and radio networks. Invitations were extended only through the various publicity media -- not directly to the invitees.

JOINT TASK FORCE ONE
STAFF ORGANIZATION - PERSONNEL DIVISION

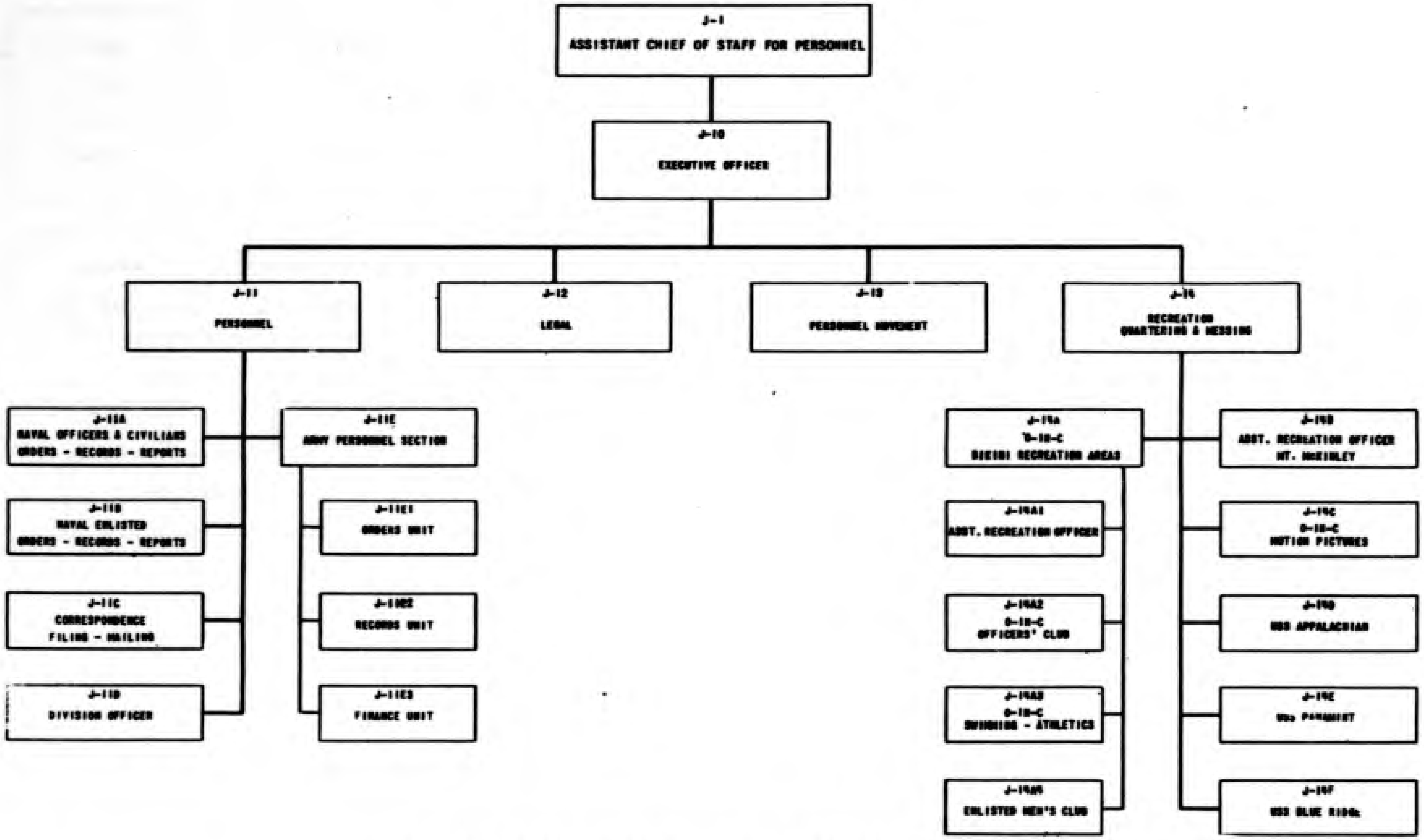

FIG. 3.2 STAFF ORGANIZATION OF PERSONNEL DIVISION

APPROVED: R. Brodie Jr
Captain, U.S. NAVY
Asst. Chief of Staff
20 MARCH 1946

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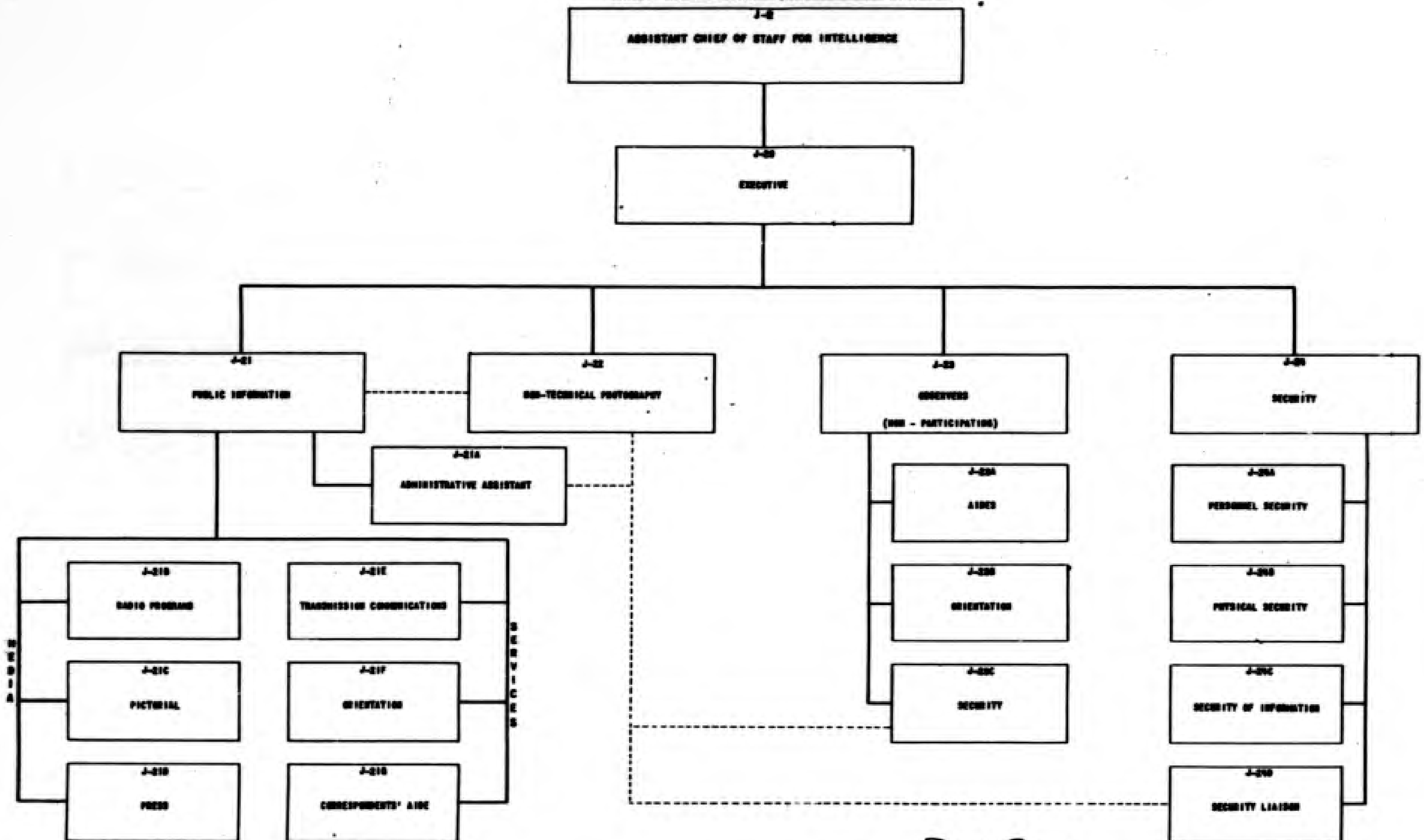
3.29

JOINT TASK FORCE ONE
STAFF ORGANIZATION INTELLIGENCE DIVISION



APPROVED:
1 MARCH 1946
Brig. Gen., U. S. Army
Assistant Chief of Staff

FIG. 3.3 STAFF ORGANIZATION OF INTELLIGENCE DIVISION

3. How to Get the Information to the Press, Pictorial, and Radio Representatives. To start the process of familiarizing the press and radio representatives with the objects of the Operation and with the Operation Plan, an "Off-the-Record Press Conference" was held on 26 Apr 46. Here a large number of the selected representatives heard extended off-the-record explanations by Commander JTF-1 and his principal assistants as to what lay ahead. Before the representatives boarded the APPALACHIAN, they were given "press packets" containing the mimeographed record of this conference and a variety of pamphlets dealing with all principal (unclassified) technical and nontechnical information of value as background. Aboard APPALACHIAN, press conferences with JTF-1 officials were held at frequent intervals. Documentary motion-picture films pertinent to the Operation were shown. A special series of lectures was provided.

At Bikini, the group made inspection tours of the target area before and after each Test. (Unfortunately, the sheer size of the group somewhat limited the extensiveness and effectiveness of these tours.) Airplane flights over the target area were also arranged.

Naturally, security requirements made it impossible to give the representatives as much concrete information on damage, injury, radioactivity, etc., as they desired.

B. Nontechnical Photography Section (J-22). Captain R. S. Quackenbush as Head of the Nontechnical Photography Section was responsible for procurement of nontechnical photographic personnel and equipment, for preparation of the Photographic Plan (Annex "L"), and for taking, developing, and releasing unclassified photographs. Acting on the advice of the Public Information Division he arranged the positions of the commercial photography representatives on A-Day and B-Day.

A Photo Review Panel was created to review (for release or classification) still and motion pictures. This Panel was situated in the U. S. Naval Photographic Science Laboratory at Anacostia, D. C.

C. Nonparticipating Observers Section (J-23). Colonel H. B. Smith, as Head of the Nonparticipating Observers Section, had charge of the foreign and domestic observers, including observers from Congress, the U. S. Armed Services, UN, Great Britain, Canada, and civilian scientist observers. (See also Sec. 3.009)

D. Security Section (J-24). Commander Charles Randall, as Head of the Security Section, was responsible for the safeguarding of all classified information and material, including classified correspondence, dispatches, photographs, and instruments. His job was an unusual one, in that the crucial information to be guarded did not consist of dates, names of places, or other individual data, such as are vital to typical military operations, but consisted, rather, of compilations and correlations of detonation data and damage results; facts not secret-appearing when isolated, became top secret when assembled.

3.018 Assistant Chief of Staff for Operations (J-3).

Captain C. H. Lyman was designated Assistant Chief of Staff for Operations (J-3) on 5 Mar 46. He was responsible for assisting and advising in all matters pertaining to Force Organization, for preparing plans and orders for the conduct of Operations, and for the execution of such orders. The most important of his duties were obtaining assignments of the necessary ships and aircraft, and directing their movements.

Fig. 3.4 shows his staff organization, which was divided into five sections -- discussed separately below:

A. Ship Operations Section (J-31). This Section, headed by Capt. W. C. Winn (Navy), directed all ship movements.

B. Air Operations Section (J-32). This Section, headed by Colonel W. D. Ganey was responsible for procuring personnel, equipment, and aircraft for the Army and Navy Air Groups, for the organization and operation of air transportation services within and outside the U. S., for the training of the Air Groups, and for the preparation of the Air Plan, Annex F.

C. Communications and Electronics Section (J-33). This section, headed by Captain K. M. Gentry (Navy), with Colonel D. F. Henry (AAF) as his deputy, was responsible for all operational communications and electronics and for the allocation of all frequencies employed during the operation. It prepared the Communication and Electronic Plan, Annex C; assigned and coordinated the use of a total of 348 frequencies ranging from 300 kcs to 30,000 mcs, (task force command and administration: 85 channels, 163 frequencies; electronic instrumentation: 107 channels, 107 frequencies; and press radio photograph, broadcast, and teletype: 11 channels, 78 frequencies). It provided the facilities and organization for handling the unprecedented volume of JTF-1 and press communications.

D. Aerology Section (J-34). Colonel B. J. Holzman assisted by Capt. A. A. Cumberledge (Navy) was responsible for the organization of the services to provide proper information for the preparation of weather forecasts for the test area; and they were responsible for analysis of the information collected and preparation of the actual forecasts. They were also responsible for the preparation of the Aerological Plan, Annex T.

E. History and Analytical Section (J-35). Captain A. B. Leggett (Navy) prepared Annex BB, "Reports," and wrote the overall Operational (nontechnical) History.

3.019 Assistant Chief of Staff for Logistics (J-4).

Brigadier General (now Col.) D. H. Blakelock was designated Assistant Chief of Staff for Logistics (J-4) on 25 Jan 46. He was responsible for all logistics matters, including transporting the Task Force's 42,000 men and providing them with military, technical and personal equipment. He was responsible for the installation of ground facilities, including photographic towers at Bikini and laboratories at Kwajalein. His transportation activities included not only surface vessel transportation but also air transportation — of personnel and freight. (Approximately 1300 persons were flown from Continental U. S. to Bikini, and back; approximately 440,000 pounds of freight were flown from Continental U. S. to Pearl Harbor or to the Marshall Islands.) He maintained field representatives at important points of assembly or transfer.

Fig. 3.5 shows his staff organization.

His work was divided among the sections discussed below:

A. Executive Section (J-40). As Head of the Executive Section, Capt. M. A. Norcross (Navy) was responsible for planning, supervising, and coordinating logistic matters within the J-4 organization and with other Staff Organizations. His responsibility included maintenance of records, distribution of information, and preparation of periodic reports.

B. Navy Supply Section (J-41). As Head of the Navy Supplies Section, Comdr. M. H. Gatchell was responsible for staff supervision of Navy supply activities.

C. Army Supply Section (J-42). As Head of the Army Supply Section, Col. F. W. Ott was responsible for Army supply activities.

D. Transportation Section (J-43). As Head of the Transportation Section, Col. A. D. Higgins was responsible for the activities pertaining to the transportation of personnel and supplies.

E. Force Maintenance Section (J-44). As Head of the Force Maintenance Section, Comdr. J. J. Fee was responsible for ship maintenance, ship repair, and boat-pool activities in the Task Force, arranging through J-3 for the procurement of necessary repair ships, tenders, drydocks, and boat-pool facilities. This section worked closely with the Force Organization's Service Group (Task Group 1.8) in the execution of these responsibilities.

F. Force Medical Section (J-45). As Head of the Force Medical Section, Capt. W. E. Walsh (Navy) was responsible for the general health and general medical care of the Task Force personnel and press and observer personnel.

G. Construction Section (J-46). As Head of the Construction Section, Comdr. K. C. Lovell was responsible for the construction or installation of shore facilities required by the Task Force. His duties included estimating requirements, preparing plans, and exercising staff supervision over construction activities in the Force.

3.020 Technical Director (013).

A. Introduction. The Technical Director (013) was one of the two technical administrators to whom the Deputy Task Force Commander for Technical Direction delegated the discharge of the majority of his technical-administrative responsibilities. (The other technical administrator was the Director of Ship Material [014].)

The responsibility of the Technical Director included planning, administration, coordination, and supervision of measurement of pressure, radiation, waves, radioactivity, and other "direct effects" of the explosion (but not determination of damage to ships and material and not determination of injury to animals).

B. Choice of Technical Director. Dr. R. A. Sawyer became Technical Director (013) of JTF-1 on 11 Jan 46. (For payroll purposes, Dr. Bradbury, acting with the approval of Maj. Gen. L. R. Groves, asked Dr. Sawyer on 9 Jan 46 to accept a nominal post as Associate Director of the Los Alamos Laboratory. Dr. Sawyer accepted and the appointment became effective on 11 Jan 46.) Dr. Sawyer was a logical choice for this position in view of his previous extensive experience in civilian and military research in applied physics; for example, he had been Director of the Armor and Projectile Laboratory at the U. S. Naval Proving Ground at Dahlgren, Va. During the Operation he was on leave of absence from the University of Michigan, which, during the summer of 1946, made him Dean of the Graduate School.

C. Technical Director's Staff. The Technical Director's immediate technical-administrative staff included Dr. E. W. Thatcher (Deputy Technical Director and Coordinator of 013 Electromagnetic

JOINT TASK FORCE ONE
STAFF ORGANIZATION OPERATIONS DIVISION

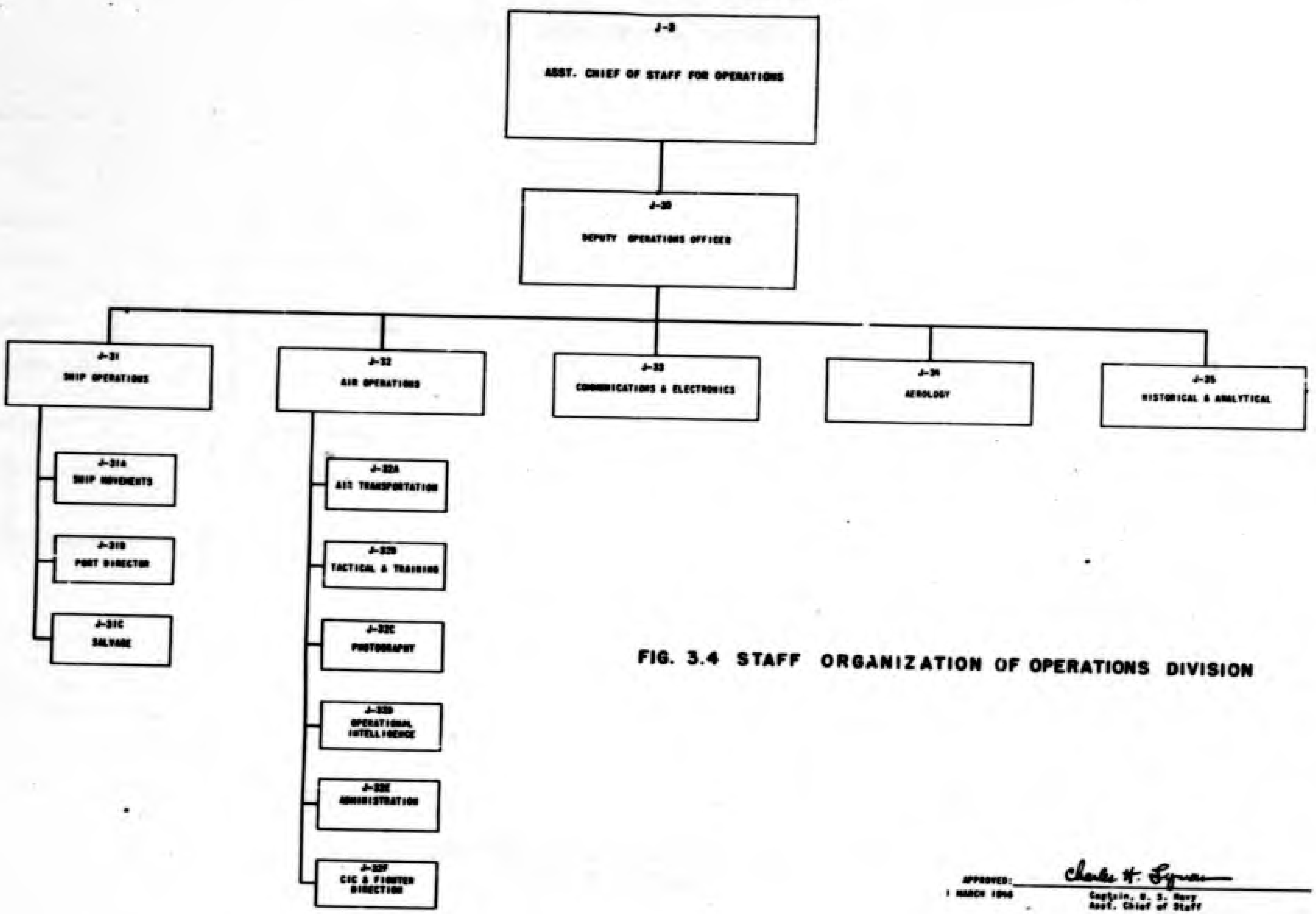


FIG. 3.4 STAFF ORGANIZATION OF OPERATIONS DIVISION

APPROVED: Charles H. Lyman
1 MARCH 1946
Captain, U. S. Navy
Asst. Chief of Staff

JOINT TASK FORCE ONE
STAFF ORGANIZATION LOGISTICS DIVISION

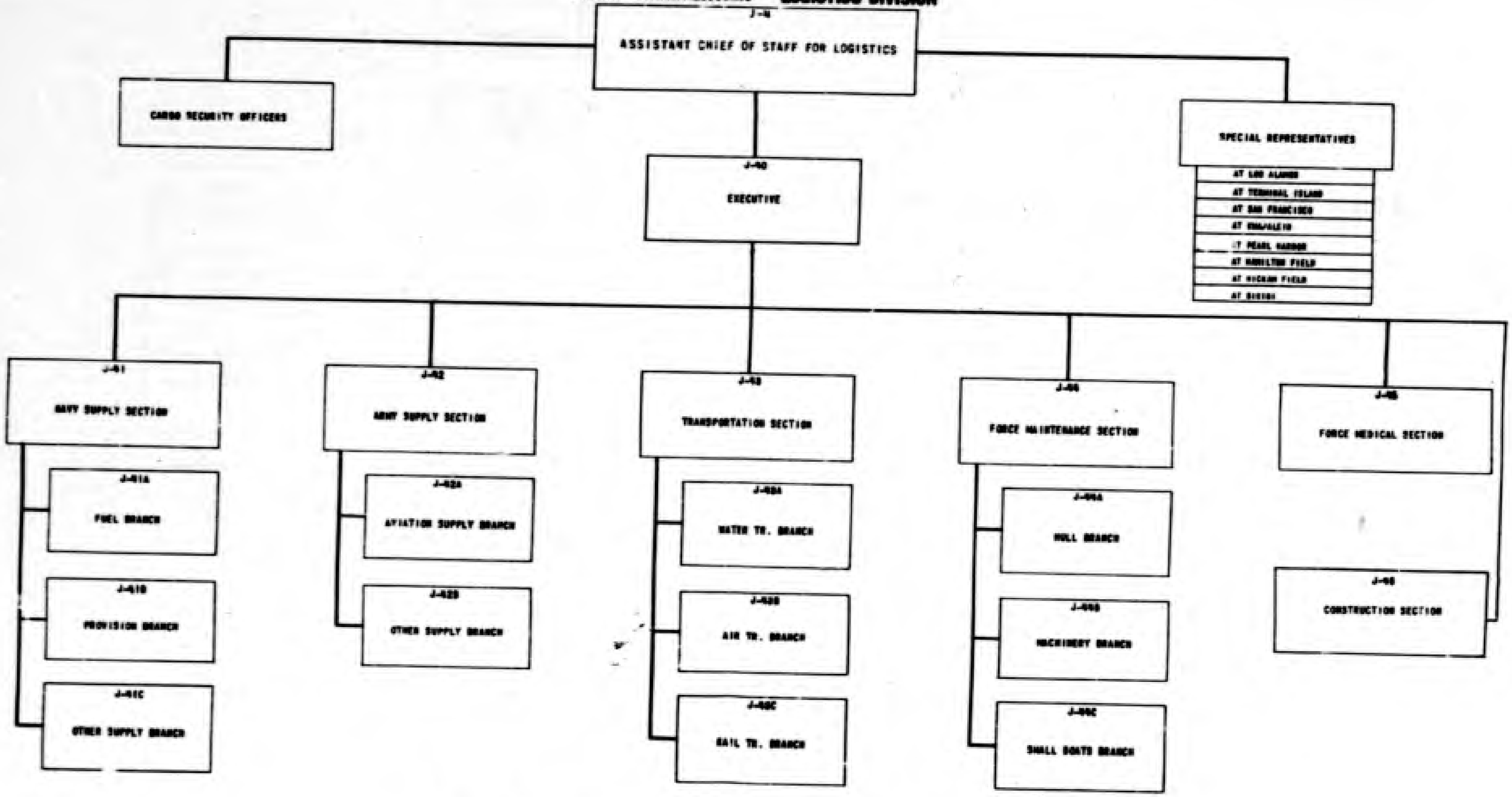


FIG. 3.5 STAFF ORGANIZATION OF LOGIST4CS DIVISION

APPROVED:
1 MARCH 1946

Brig. Gen., U. S. Army
Assistant Chief of Staff

Propagation and Electronics), Capt. F. L. Riddle (Navy), Comdr. E. S. Gilfillan, Comdr. A. W. McReynolds, Lt. Comdr. J. K. Debenham, Ens. H. M. Archer, and others.

D. Functional Organization of Technical Director's Group. The Technical Director's Group can be described both from the functional (technical) point of view and from the administrative point of view. We shall discuss the former first.

For purposes of functional coordination and report writing the Technical Director's activities were arranged in nine sections each of which had a coordinator. The section symbols, section names, and coordinators are listed below:

013 Section Symbol	013 Section Name	Coordinator
I	Bomb Operation	Dr. M. G. Holloway
II	Pressure and Impulse Measurements	Dr. W. C. Penney
III	Oceanography	Comdr. Roger Revelle
IV	Electromagnetic Propagation & Electronics	Dr. E. W. Thatcher
V	Radioactivity	Col. S. L. Warren
VI	Optical Radiation	Dr. E. O. Hulbert
VII	Nuclear Radiation	Dr. M. G. Holloway
VIII	Remote Measurements	Comdr. George Vaux
IX	Technical Photography	Capt. R. S. Quackenbush (Navy)

Many of these sections had little or no administrative frame work.

The full functional scopes of these sections are discussed in detail in later chapters.

E. Administrative Organization of Technical Director's Group. For administrative purposes, the Technical Director's Group was divided into the groups indicated below: (In some instances the group names given below are not the names formally assigned by the Technical Director but are informal names introduced in this Report for greater clarity.)

Symbol	Name	Head
013A2	013 Pressure Group (Cans and Drums)	Dr. W. G. Penney
013B	013 Oceanography Group	Comdr. Roger Revelle
013C	013 BuShips Instrumentation Group	Comdr. C. H. Gerlach
013D	013 Electronics Group	Capt. C. L. Engleman (Navy)
013E	013 Radioactivity Group	Col. S. L. Warren
013G	013 BuOrd Instrumentation Group	Capt. A. E. Uehlinger (Navy)
013H	013 Los Alamos Group	Dr. M. G. Holloway
013J	013 Remote-Measurements Group	Comdr. George Vaux
013K	013 Technical Photography Group	Capt. R. S. Quackenbush (Navy)
013L	013 AAF Electronics Group	Col. D. F. Henry

1. 013A2 The 013 Pressure Group (Cans and Drums). This Group was responsible for those pressure measurements made using pipes, cans, and drums. It was headed by Dr. W. G. Penney, a British subject who had been an adviser to the Theoretical Physics Division of the Los Alamos Laboratory. Personnel were berthed on the WHITING.

2. 013B The 013 Oceanography Group.

(a) Function. This Group was responsible for making predictions and measurements of wave motion; for determining the effects of the bomb explosions on the water, and on living things inside and outside the Atoll, and on the sediments and structure of the Atoll itself; in addition it was responsible for certain phases of the prediction and measurement of radioactivity in the water.

In its wave-motion work, the Group was responsible for determining: wave height as a function of distance from the explosion in both deep and shallow water (maximum height and also height as a function of time); wave velocity, period, length, shape, stability; also seismological phenomena of all kinds in Bikini Atoll area. In its other oceanographic activities, it was responsible for studies in the fields of: physical oceanography (including direction and velocity of currents, velocity gradients, tide heights, water interchange between lagoon and open sea, temperatures, and chemical characteristics of the water, diffusion rates, effects of winds); biology (including pelagic, lagoon, and land plants and animals of all kinds); geology (including physical geology, physiography and sedimentary geology of ocean bottom, lagoon bottom, and shores).

In predicting and measuring radioactivity, the Group was responsible for making surveys of probable diffusion and transport rates of lagoon and ocean waters, carrying out special sampling and measuring programs, and providing special personnel and equipment.

(b) Organization. The Group was headed by Comdr. Roger Revelle, BuShips, who was also attached to the Navy's Hydrographic Office. Principal assistants in the Oceanography Survey Section under Lt. Comdr. C. A. Barnes were Lt. Comdr. J. R. Lyman, (Oceanographic work in support of radiological reconnaissance), Lt. Comdr. M. C. Sargent (biology and geology), and Capt. M. A. Traylor (Army) (fisheries). Working with Lt. Comdr. F. G. Morris in the Wave Measurement Section were Mr. N. J. Holter (wave motion) and Comdr. Beauregard Perkins, Jr. (seismology).

Initially the Group consisted only of a wave-motion unit; later the Oceanographic Surveys Section was added; finally, the arrangements for supporting the radioactivity program were developed. At the height of its activities the group included over 80 persons.

Besides BuShips and Service branches participating in the Group, the following civilian groups participated:

- U. S. Geological Survey
- U. S. Fish and Wildlife Service
- U. S. National Museum (Smithsonian Institution)
- U. S. Coast and Geodetic Survey
- University of California (Department of Engineering and Scripps Institution of Oceanography)
- University of Michigan
- Division of Fish and Game, Commission of Agriculture and Fisheries, T. H.
- Geotechnical Corporation
- Woods Hole Oceanographic Institution

(c) Activities. Before and after formation of JTF-1 many model studies of water motion in shallow basins were made using conventional explosives. These tests were made at the Navy's David Taylor Model Basin, the Naval Warfare Mine Test Station and the Woods Hole Oceanographic Institution. Other model tests were carried out by the U. S. Navy Electronics Laboratory. The results were of considerable value to the 013B Group in planning its Bikini activities.

Even two months prior to the formal creation of JTF-1, Mr. N. J. Holter and Comdr. Roger Revelle had given much thought to using (in the proposed atomic bomb tests) various techniques developed by BuShips for measuring waves. Proposals were made, approved in principal, and developed in considerable detail well before 5 Feb 46 when Comdr. Revelle reported for duty as Head of the 013B Group. Valuable supplementary proposals were received from many of the civilian agencies which later participated actively.

The BOWDITCH (AGS-4) was the principal ship of the Oceanographic Survey Section of the Group. She arrived at Bikini on 10 Mar 46 carrying representatives of nearly all agencies participating in the oceanographic work. She was in fact the center of the early JTF-1 activities at Bikini.

Other ships supporting the activities of the Oceanographic Survey Section were:

BLISH (AGS-10)
GILLIS (AGS-13)
HAVEN (APH-112)
YP-636
YMS-354
YMS-358
YMS-413

The Wave Measurement Section was berthed on FULTON.

Activities were not confined to Bikini, but included also: Kwajalein, Eniwetok, Rongerik, Rongelap and Wotho.

The Group played an especially large role in Test B, where wave phenomena and lagoon water contamination were of major importance. Detailed predictions were made before Test B, and analyses and recommendations were made periodically after Test B.

3. 013C The 013 BuShips Instrumentation Group.

(a) Function. This Group was responsible for studying ship response and the phenomena directly producing the response. The program included measurement of: pressure outside and inside ships, and underwater; winds; impulse and velocity imparted to ship structures; acceleration; roll and pitch; strains and displacements; temperature outside and inside ships; change in magnetization of ships.

(b) Organization. This Group was headed by Comdr. C. H. Gerlach, of BuShips. His principal assistants were Comdr. R. M. Langer, Lt. Comdr. L. S. Beedle, and Lt. Comdr. F. J. Dellamano. Acting as assistants and also providing liaison with various cooperating agencies were Mr. E. E. Johnson and Dr. G. E. Hudson (David Taylor Model Basin), Dr. Irwin Vigness and Mr. P. J. Walsh (Naval Research Laboratory), Mr. H. E. Jensen and Mr. C. F. Kasanda (BuShips), and Mr. F. J. Friel (Norfolk Naval Shipyard).

Important support was given the Group not only by BuShips and the agencies mentioned above but also by New York Naval Shipyard; other agencies consisted of: the Philadelphia Naval Shipyard, the Naval Ordnance Test Station, Inyokern, Calif., the Naval Torpedo Station, Newport, R. I., and the U. S. Naval Engineering Experiment Station at Annapolis, Md.

(c) Activities. The Group was created on 7 Jan 46; it was to some extent an outgrowth of the Underwater Explosion Research Group of BuShips. The program of the Group was laid down at an important conference on 7 Jan 46 attended by Vice Adm. Blandy and also by representatives of the Los Alamos Laboratory. The following months were occupied principally with designing, procuring, and shipping the special instruments required.

At Bikini the Group was berthed principally on the WHITING and was occupied principally with installing and testing the instruments and -- after each Test -- reading and interpreting the recorded results.

4. 013D The 013 Electronics Group.

(a) Function. The principal functions fulfilled by this Group were: arranging technical communications as for certain supplementary timing signals; arranging the telemetering of data of many kinds; modifying, installing, and servicing a great variety of instruments containing electronic components; measuring electromagnetic propagation anomalies produced by the explosions; assisting in the remote-measurements program; and assisting the drone boat and radiological safety programs. (The Group was not responsible for the bomb-detonating timing signals, nor for the "black-box" instrument-starting program.)

(b) Organization. This Group was essentially identical to the "Electronics Coordinating Group," a dual-responsibility group reporting both to the Technical Director (013) and to the Director of Ship Material (014) (discussed in Sec. 3.021). Capt. C. L. Engelman of BuShips was head of the Group. Reporting to his principal assistant, Dr. T. D. Hanscome, were Comdr. J. L. Miller (Administration), Comdr. J. E. Rice (Inspection), Comdr. J. G. Houpis (Instrumentation and Shore Stations), Dr. D. G. Fink (Technical Reports), and Comdr. F. X. Foster (Communications). Other principal assistants to the Group were Lt. Comdr. R. L. Reaser and Lt. Lawrence Bershad (Navy).

(c) Activities. The Electronics Coordinating Group was established on 21 Jan 46. Over 60 projects were soon in the planning stage, and assistance was obtained from a large number of Service groups, (particularly from BuAer, Naval Research Laboratory, and Signal Corps), industrial corporations, and university staffs. Personnel rapidly increased, finally including over 72 Naval officers, 1 Army officer, and 78 civilians. The majority of these persons left Oakland, Calif., 6 May 46 on AVERY ISLAND, bound for Bikini.

5. 013E The 013 Radioactivity Group.

(a) Function. This Group was responsible for the protection of personnel of the Task Force from the hazards peculiar to the atomic bomb and to help enable personnel to return safely to the target area at the earliest possible moment. In addition the Group was responsible for making all measurements of radioactivity required in order to estimate the effectiveness of the explosion in producing casualties to target vessel crews. The work involved the prediction of all nuclear radiation intensities (including alpha, beta, and gamma activities and neutron flux; the measurement of the radioactivity in the air, water, and material, on target and operational vessels, and near experimental animals and instruments; the measurement of the exposure of all personnel; and the measurement of gamma and neutron doses on the target ships). (This Group was an operating group, and is not to be confused with 016, the Radiological Safety Adviser. The 013E Group was not responsible for measurements of neutron and gamma-ray intensities bearing solely on the energy release of the bombs.)

(b) Organization. The Group was headed by Col. S. L. Warren, who had served as Chief of the Manhattan Engineer District Medical Section and who was on leave of absence from the University of Rochester.

Colonel Warren was assisted by Col. A. A. deLorimier, Capt. R. J. Buettner, Comdr. D. L. Kauffman, Dr. Herbert Scoville, Jr., Dr. Joseph Hamilton, Dr. Kenneth Scott, Dr. Gerhard Dessauer, Dr. Lauren Donaldson, and Mr. Donald Collins.

(c) Activities. This Group, berthed principally on the HAVEN, analyzed thousands of radiation-recording devices which had been placed on all target vessels and distributed to personnel of the Task Force. For days and in some cases months after the Tests, monitors with radiation-detecting instruments carried out extensive patrols of the Lagoon, target ships, islands, the air, and the ocean outside the Lagoon until no danger from radioactivity remained. Samples of marine life, water, sand, and ship materials were collected and their radioactivity measured.

Perhaps the Group's greatest difficulty was in securing and training enough radioactivity monitors. The peak strength of the group was approximately 350, but of this group only 150 were available on any one day for monitoring duty in clearing target vessels, instruments, and installations, for example, on the seventh day after B-Day when the demands were at a peak. The remaining personnel were required for administration, maintenance of the instruments used by the monitors, analyses of samples of water, measurement of the film badges, and the other numerous technical activities in which the Group was engaged.

6. Remarks re the Defunct Group O13F. Originally, the symbol O13F was applied to the Bomb Operation Group of the O13 Los Alamos Group. Later, all the Los Alamos personnel participating in JTF-1 were placed in one administrative group given the symbol O13H -- which is discussed in Para. 8 of this Sec.

7. O13G The O13 BuOrd Instrumentation Group.

(a) Function. This Group -- one of the largest of the O13 groups -- was responsible for a great variety of measurements in the fields of pressure and optical radiation. Among the phenomena measured were the following: Pressure and impulse in the air and in the water; orientation of vessels with respect to the Zeropoint; shock-wave velocity; amount, quality, and time variation of the optical radiation.

(b) Organization. This Group was led in the field by Capt. A. E. Uehlinger of BuOrd; Dr. G. K. Hartman was Technical Director of the Group. Capt. L. W. McKeehan (Navy) served as adviser. Comdr. Stephen Brunauer played an important part in the early planning. The Group's six subgroups (and their heads) were:

Air Blast Subgroup (Dr. C. W. Lampson)
Underwater Subgroup (Dr. A. B. Arons)
Low Frequency Subgroup (Dr. J. V. Atanasoff)
Radiometry Subgroup (Comdr. S. S. Ballard)
Pressure-Time Subgroup (Dr. J. E. Henderson)
Service Subgroup (CWO J. P. Orr)

(c) Activities. Several months before JTF-1 was created, BuOrd gave much attention to determining the effects of large underwater explosions on naval vessels, by using a charge of several hundred tons of conventional explosive. This planning was accelerated when the atomic bomb tests against naval vessels appeared definitely in prospect. The Group held important meetings on 21 Dec 45, 7 Jan 46, and 30 Jan 46.

After completing the majority of its planning and procurement program, the Group moved forward to Bikini, arriving there 29 May 46 and was berthed principally on WHITING.

8. O13H The O13 Los Alamos Group.

(a) Function. This Group was responsible for preparing the "black-box" instrument-starting devices, sending the principal timing signals, assembling the bombs, delivering Bomb B, detonating Bomb B, measuring certain phenomena accompanying the detonations proper, and determining the energy release. (Originally, the black-boxes had been made a responsibility of BuShips and the Naval Research Laboratory; however, the responsibility was transferred almost at once to the 013H Group at the request of that Group. See a later chapter for a retrospective analysis of the black-box program.)

This Group was responsible in varying degrees to three different individuals or groups. In maintaining security as to the bomb itself, it was responsible to Dr. N. E. Bradbury, Director of the Los Alamos Laboratory; and, through Dr. Bradbury, to the Commanding General of the Manhattan Engineer District. In matters of general policy and particularly in regard to the actual detonating of the bombs, its line of responsibility extended directly to the Deputy Task Force Commander for Technical Direction. In matters requiring coordination with other technical groups it was responsible to the Technical Director.

(b) Organization. Dr. M. G. Holloway was in charge of this Group. Mr. R. S. Warner, Jr., was his principal assistant. Dr. N. E. Bradbury was present in an advisory capacity, although not formally a participant in the Operation.

The 013H Group included the following subgroups:

Subgroup	Person in Charge
Bomb Operation	Mr. R. S. Warner, Jr.
Bomb Instruments	Dr. M. G. Holloway
Measurements of Instantaneously-Produced Gamma Rays	Dr. N. N. Nereson
Measurements of Fast Neutrons	Dr. G. A. Linenberger
Radiochemistry of Bomb Products	Dr. William Rubinson
Measurements of Delayed Gamma Rays, etc.	Dr. J. L. Tuck
Photography of the Detonation	Dr. B. Brixner
Condenser Gage Measurements	Dr. J. Wieboldt
Time Signals	Dr. J. Wiesner and Dr. H. Weiss
Detonation Phenomena in General	Dr. J. Hirshfelder

(c) Activities. The Group was berthed on ALBEMARLE and CUMBERLAND SOUND. For Test A, ALBEMARLE was at Kwajalein.

Bomb A was handed over by the O13H Group to Task Group 1.5 at the special bomb pit on Kwajalein shortly before the dawn take-off of the B-29 "Dave's Dream." The Group had no responsibility for the aiming and releasing of the bomb, but it did provide two specialists, Ens. D. L. Anderson and Mr. L. D. Smith, to accompany the bomb on the trip to Bikini and, before the final run, to assist in assembly and tests.

Whereas the task of preparing and delivering the bomb for Test A presented no new difficulties, preparing and delivering the bomb for Test B presented a number of new and major difficulties. Principal tasks were: rapidly designing, constructing, shipping, and testing the bomb container; arranging for the lowering of the bomb and its container to the proper depth and keeping it there under good mechanical control; developing a method of obtaining from the bomb, in the instant prior to the bursting of its case, the data needed in the gamma-ray-timing method of evaluating the efficiency of the detonation; providing a foolproof system for remotely detonating the bomb at the desired instant and with no danger of premature detonation.

9. O13J The O13 Remote-Measurements Group. This Group was responsible for finding the extent to which the occurrence of an atomic bomb explosion could be detected at great distances. Detection methods included collection of radioactive materials from the air, seismological measurements, measurements of anomalies in terrestrial magnetism, atmospheric pressure and conductivity, and ionospheric reflectivity. The individual field groups were located at widely spaced stations, including: Honolulu, Hawaii, Kwajalein, Eniwetok, Guam, Wake, Midway, Manila, Philippine Islands; Nome, Alaska; Sitka, Alaska; Juneau, Alaska; Anchorage, Alaska; San Francisco, Calif.; Mt. Wilson, Calif.; Santa Ana, Calif.; San Leandra, Calif.; Seattle, Wash.; Bozeman, Mont.; Portland, Oregon; Tucson, Ariz.; Kingsville, Tex.; Grand Island, Nebr.; Rapid City, S. Dak.; St. Louis, Mo.; Chicago, Ill.; Washington, D. C.; Cheltenham, Md.; Whiteoak, Md.; Watheroo, Australia; Huancayo, Peru; San Juan, Puerto Rico; Grafenwohr, Germany.

This Group was headed by Comdr. George Vaux, of the Navy's Office of Research and Inventions (now Office of Naval Research). Dr. J. Dutka was his principal assistant. Many Service and civilian agencies participated in the work, including the following:

Office of Research and Inventions (now Office of Naval Research), including Naval Research Laboratory
Naval Ordnance Laboratory
Puget Sound Naval Shipyard
U. S. Signal Corps, including Evans Signal Laboratory
Federal Communications Commission
U. S. Department of Commerce (including the Coast and Geodetic Survey and the National Bureau of Standards)
U. S. Geological Survey
Franklin Institute (including the Bartol Foundation)
Geotechnical Corporation
Harvard University
Montana State College
South Dakota School of Mines
Stanford University
University of Chicago
University of Louisiana
Dept. of Terrestrial Magnetism of the Carnegie Institution of Washington
Mt. Wilson Observatory, Carnegie Institution of Washington
University of Texas
University of Washington

Maintaining administrative contact with the various field stations was particularly difficult in view of the wide separation of the stations and the difficulty of transmitting highly classified material between outlying stations and the central office in Washington, D. C.

10. O13K - The O13 Technical Photography Group. The O13K Group was mainly a service and coordinating group — not strictly a technical-administrative group. Thus certain subgroups such as the Bomb Detonation Photography Subgroup (O13H) acted almost entirely independently in planning and executing their individual technical photographic programs.

The scope of JTF-1 technical photography activities included: still and motion-picture photographs; black-and-white and color photographs; photographs taken on land, sea, and from airplanes, and underwater; manually triggered and automatically triggered photographs; normal-speed, and high-speed motion-picture photographs; photographs taken using stationary film, and continuously-moving-strip photographs taken using continuously moving film; photographs of the explosion proper and photographs of instruments (radar PPI presentations, icaroscope screens, etc.).

The coordination of technical photography was under the direction of Capt. R. S. Quackenbush, (Navy). Lt. Comdr. J. K. Debenham prepared the Technical Director's general report on results of the technical photography program. Nearly all technical groups assisted the technical photography program.

Force Organization groups giving much support included Task Units 1.2.7; 1.5.6; 1.5.21; 1.5.22; 1.6.14; 1.6.23; 1.6.24; 1.6.33. Much support came also from U. S. Naval Photographic Science Laboratory at Anacostia, D. C. and the Naval Air Base at Kwajalein. Other military groups, industrial concerns (especially Fairchild Camera and Instrument Corporation and the Eastman Kodak Company), and educational institutions assisted also.

Elaborate plans for taking technical photographs were prepared and essentially completed during January and February 1946, the details being recorded in Operation Plan, Annex G.

Special towers for mounting cameras were erected on Bikini, Amen, and Enyu -- the three islands nearest the Zeropoint. Seventy-five-ft steel towers were used, these being the standard Navy type available.

Although some film was processed at Bikini and at Kwajalein, the majority of the film was flown back to U. S. and processed and reproduced by the U. S. Naval Photographic Science Laboratory, Anacostia, D. C. Other film was processed and held at Wright Field, Dayton, Ohio. Certain films requiring special processing were handled by the Eastman Kodak Company, Ansco Corporation, Hal Roach Studios, Consolidated Films, or Technicolor Corporation.

A considerable fraction of the film gathered together at the U. S. Naval Photographic Science Laboratory at Anacostia, D. C. was subject indexed; however, the quantity of film concerned was so large that an appreciable fraction of it had not been indexed even by 1 Sept 46.

No figures are available as to the quantity of film exposed for technical purposes.

11. 013L The 013 AAF Electronics Group. This Group was responsible for making a number of studies in the field of electronics, including effects of the explosions on airborne radar equipment, extent to which the mushroom could be detected using airborne radar, and effects of the explosion on radio signals transmitted from planes and land stations.

These activities were under the immediate supervision of Col. D. F. Henry of the Army Air Forces. Principal support came from Task Group 1.5.

F. Activities of the Technical Director. The Technical Director assembled his immediate technical staff during January, February, and March of 1946. He participated in many conferences on technical plans and helped determine the scope and extensiveness of the activities of the various technical groups. Proceeding from preliminary plans advanced at an instrumentation conference on 30 Jan 46 he submitted to the Deputy Task Force Commander for Technical Direction on 8 Feb 46 a memorandum proposing a complete and detailed technical program, which later became Annex G to the Operation Plan.

The Technical Director arrived at Bikini on 29 May 46 and was berthed on WHITING. He attended numerous staff, technical, and press conferences, directed all instrumentation programs, inspected technical installations, altered certain plans to fit field exigencies, and arranged for the preparation of reports. When, after Test B, it became apparent that too few radiological safety monitors and too few divers were assisting the recovery of instruments, he arranged, through Commander JTF-1, to have additional personnel transferred to this work.

After his return to Washington, D. C., on 19 Aug 46 he coordinated the writing of reports by 013 groups, and arranged the completion of a retrospective revision of his plan of operation--Annex G.

3.021 Director of Ship Material (014).

A. Introduction. The Director of Ship Material (abbreviated DSM; code 014) was one of the two technical administrators to whom the Deputy Task Force Commander for Technical Direction delegated the majority of his technical-administrative responsibilities. (The other technical administrator was the Technical Director, 013.)

DSM was responsible for the administration, coordination, and supervision of those activities concerned with determining damage to ships, damage to materials, and injury to animals and plants (i.e., activities concerned with determining "permanent," practical, strategic, and tactical effects of the atomic bomb explosions). The responsibility included preparing both the target and non-target ships, preparing and exposing the various materials in which graded damage was desired, determining their exact conditions before and after the explosions, drawing conclusions as to the types and extent of damage caused by the explosions, distinguishing between damage caused by the direct effects of the explosion and damage caused by indirect effects such as fire and flooding, and estimating what injury would have been inflicted on personnel. DSM was responsible also for damage control, salvage and repair, and after Test B for decontaminating radioactive vessels and material.

B. Choice of Director of Ship Material. Rear Admiral T. A. Solberg was designated Director of Ship Material in January 1946. His designation was a logical one. He had been head of the BuShips Research and Standards Branch and had served with the Tolman Committee on Postwar Planning on Nuclear Physics. In April 1946 he became Assistant Chief of Naval Operations (Atomic Power).

C. DSM's Staff. The Director of Ship Material's principal assistant was Capt. L. A. Kniskern (Navy). His other assistants were:

	Responsible for:
Capt. F. W. Slaven (Navy)	Target Ships
Capt. F. X. Forest (Navy)	BuShips Preparation
Comdr. E. H. Batcheller	BuShips Preparation
Lt. Comdr. L. H. Roddis, Jr.	Non-Target Vessels
Lt. Comdr. L. R. Glosten	Loading and Problems of Naval Architecture

D. Organization of the DSM Group. The DSM Group was organized as indicated below. Besides the formally assigned names, informal names are indicated, these latter being used ordinarily in this History for convenience and in order to remove any implications that the groups had formal administrative connections with the permanent Navy Bureaus.

Symbol	Formal Name	Informal Name Used in this Official History
014B-H	Army Ground Group	DSM Army Group
014J	BuAer Group	DSM Aeronautics Group
014K	BuShips Group	DSM Ships Group
014L	BuOrd Group	DSM Ordnance Group
014M	BuM&S Group	DSM Medical Group
014N	none	DSM Electronics Group
014S	BuS&A Group	DSM Supplies Group
014Y	BuY&D Group	DSM Yards and Docks Group

These groups are discussed separately below:

1. DSM Army Group (014B-H).

(a) Functions. This Group was responsible for exposing and inspecting a wide variety of Army equipment and for determining the effects of atomic bomb explosions on such equipment.

(b) Organization. Colonel J. D. Frederick was head of this Group. Col. J. H. Weber was his Executive Officer. The seven units comprising the Group were:

Unit Symbol	Unit Name	Unit Head
014B	(Commanding Officer)	(Col. J. D. Frederick)
014C	Engineer Unit	Lt. Col. S. B. Smith
014D	Signal Unit	Capt. C. H. Wollenberg (Army)
014E	Ordnance Unit	Lt. Col. S. F. Musselman
014F	Chemical Unit	Capt. H. C. Adams (Army)
014G	Quartermaster Unit	Col. L. P. Jordan
014H	Air Unit	Maj. E. K. Walters

The Group drew its personnel from -- and was essentially identical to -- Task Group 1.4.

(c) Activities. The Group exposed a great variety of Army material ranging from ammunition and petroleum to field stoves and clothing. The majority of the equipment was exposed on the weather decks of target vessels in order to approximate a situation obtaining in open fields. The Group reported and appraised the results.

The Group was berthed on WHARTON.

2. DSM Aeronautics Group (014J).

(a) Function. This Group was responsible for: (a) providing aircraft and aeronautical equipment for testing; (b) exposing this material and inspecting it before and after the Tests; (c) providing special instruments to be placed in Navy drone planes; and (d) determining damage and radioactivity in these planes.

(b) Organization. This Group was headed by Capt. T. C. Lonnquest (Navy) of BuAer. His principal assistant was Capt. J. E. Dodson (Navy), Executive Assistant and also head of Aircraft Power Plants Unit. Comdr. J. K. Leydon (Navy) was Rear Echelon representative and also Liaison Officer for Pilotless Aircraft. Capt. Lonnquest's principal units and their heads were as follows:

Unit Name	Unit Head
Aircraft Power Plants	Maj. J. W. Morrison
Aircraft Armaments	Comdr. J. R. Reedy
Aircraft Electronics and BuShips Liaison	Lt. E. V. Sizer (Navy)
Aircraft Structures	Lt. Comdr. G. V. Schliestett
Aircraft Equipment	Lt. Comdr. W. A. Hopkins
Catapults and Arresting Gear	Lt. J. A. Torrey (Navy)

(c) Activities. This Group was created on 21 Jan 46. In the weeks immediately preceding Test A it installed velocity and acceleration gages in various target aircraft; placed 5-gallon-can pressure gages in cockpits of various target aircraft; examined fuel tanks of target aircraft to insure that explosive mixtures were avoided; removed protective coverings from target aircrafts' cockpits and engines; cleaned aircraft guns and equipment; made final adjustments of electrical circuits and switches; unlocked aircraft guns and set them in final angles of train; loaded aircraft; photographed and listed final conditions of aeronautical material.

After the Tests, the Group concentrated on appraising and reporting damage and other effects of the atomic bomb.

The Group was berthed on WHARTON and AVERY ISLAND.

3. DSM BuShips Group (014K).

(a) Function. This Group was responsible for: (a) preparing target vessels; (b) preparing certain non-target vessels; (c) determining the effects of the atomic bomb explosions on the target vessels; (d) carrying out radioactivity decontamination measures; and (e) assisting the Director of Ship Material in coordinating his various activities.

(b) Organization. The Group was originally headed by Capt. L. A. Kniskern (Navy). However, in a reorganization while the Group was en route to Bikini, Capt. L. A. Kniskern (Navy) was made Deputy Director of Ship Material; Capt. F. W. Slaven (Navy) was made head of the Planning Group; Capt. R. C. Bell (Navy) was made head of the Target Inspection Group and Capt. F. X. Forest (Navy) was made head of the BuShips Group.

The DSM BuShips Group originally contained the following units:

Unit Name	Unit Head
Combatant Ship Unit	Capt. F. X. Forest (Navy)
Auxiliary Ship Unit	Capt. R. C. Bell (Navy)
Submarine Unit	Comdr. C. L. Gaasterland
Watertight Integrity and Survey Unit	Lt. (j.g.) J. F. DiStefano

In the reorganization, however, the Group was divided into Hull, Machinery, and Electrical units, rather than by units responsible for individual ship types. Comdr. J. W. Roe headed the Hull Unit; Capt. W. S. Maxwell (Navy) headed the Machinery Unit; and Capt. P. S. Creasor (Navy) headed the Electrical Unit.

(c) Activities. The Group was formed in January 1946. It devoted much effort to planning the ship preparation and inspection programs, advising on the target array, placing the target vessels in required condition, and planning the construction or installation of laboratories, air conditioning systems, and other special facilities required in the non-target vessels. It prepared the Operation Plan Annexes W and X entitled "Ship Preparation Plan" and "Reboarding and Inspection Plan," respectively.

At Pearl Harbor this Group was occupied not only with preparing the vessels but also with making many preliminary surveys and proving the inspection schemes.

At Bikini, extensive final preparations were made; before and after each test, the prescribed inspection programs were carried through. Detailed reports, analyzing the damage with a view toward future ship design, were written. (See Chap. 7 for a detailed account.)

The Group was berthed on **WHARTON**.

4. DSM Ordnance Group (014L).

(a) Function. This Group was responsible for obtaining and exposing Naval Ordnance equipment (other than Naval aeronautical ordnance equipment) and appraising damage done.

(b) Organization. The Group was headed by Capt. E. B. Mott (Navy) of BuOrd. His principal assistants were Comdr. A. S. Freedman (Executive Officer) and Capt. C. S. Piggot (Navy) (Adviser). The names and heads of his six principal units were as follows:

Unit Name	Unit Head
Fire Control Section	Comdr. Edgar O'Neill
Guns and Mounts Section	Comdr. F. W. Russe
Explosives Section	Comdr. H. C. Dudley
Aviation Ordnance Section	Lt. Comdr. H. B. Taylor
Underwater Ordnance Section	Lt. Comdr. H. M. Tatum
Armor and Metallurgy Section	Lt. Comdr. T. W. Johnson

(c) Activities. The Group was formed in January 1946. It obtained a wide variety of ordnance equipment, prepared inspection plans, arranged the equipment for exposure, made final tests and inspections. After each Test, determination was made of damage done.

The Group was berthed on **WHARTON**.

5. DSM Medical Group (014M). This Group was actually a combination of two relatively independent sections, which were responsible

collectively for exposing animals, determining the kinds and extents of injury, carrying out research as to the most effective methods of diagnosing injury, evaluating methods of treatment, and also for evaluating hazards other than radioactivity to which damage control and other initial boarding personnel might be exposed.

Captain G. M. Lyon (Navy) was head of this Group. (He was also JTF-1 Safety Adviser.)

The two sections of the Group are discussed separately below:

(a) DSM Damage Control Safety Section (014M1).

(1) Function. This Section was responsible for evaluating and reducing the hazards (other than radioactivity hazards) to damage control personnel and other initial boarding personnel, and for supplying medical safety officers to accompany the boarding parties aboard ships not known to be safe. Among the hazards involved were:

- Mechanical hazards, including danger from falling objects, slippery (oil-covered) surfaces, weakened ladders, decks, gratings, and weakened tanks under pressure.
- Drowning in flooded compartments.
- Fires; escaping steam; hot surfaces.
- Electrical shocks due to damaged wiring and short circuits.
- Chemical hazards due to carbon monoxide, carbon dioxide, nitrous gases, alcohol and other vapors, ammonia, corrosive acids and alkalies, creosol cleaning solutions.
- Miscellaneous hazards, including contaminated drinking water and food, escaping gases from chemical warfare munitions, secondary explosions of ammunition or acetylene.

(2) Organization. The Section was headed by Capt. Oscar Schneider (Navy). His principal assistant was Comdr. Marshall Cohen, who also served as Training Officer. The Section contained these units:

Unit Name	Unit Head
Administration Unit	Lt. Harry Browdy (Navy)
Training Unit	Comdr. Marshall Cohen
Material Unit	Lt. (j.g.) A. L. Rogers
Security Unit	Lt. G. W. Morrison, Jr. (Navy)

The Section also included a panel of eleven damage control safety officers, with Lt. Comdr. J. J. McCoy as Senior Damage Control Officer.

(3) Activities. Captain Schneider was made head of the Section on 19 Feb 46. Following extensive damage control training, the Section moved to the west coast for preliminary inspection of the target vessels and to train ships' company boarding parties. This work continued at Bikini, where they arrived 14 June 46. The A-Day and B-Day programs were carried through without incident.

The Section was berthed on HAVEN.

(b) DSM Naval Medical Research Section (014M2).

(1) Function. The Section was responsible for the biological research program which involved exposing animals, seeds, bacteria, medical and dental materials, and for studying the resulting damage and injury. Principal animals included were goats, pigs, guinea pigs, rats, and mice. Effects on animals and materials were to be correlated with pressure, radiation, etc. Measurements and predictions were to be made as to injury which would have been inflicted on ships' crews. Also methods of diagnosis and treatment were to be explored.

(2) Organization. Captain R. H. Draeger (Navy) of BuMed was Head of the Section, and Capt. Shields Warren (Navy) was Executive Officer. The Section contained these units:

Unit Name	Unit Head
Biophysics Radiation Studies Unit	Comdr. R. H. Lee
Pathology Unit	Comdr. J. L. Tullis
Radiobiology Instrumentation Unit	Lt. Comdr. R. E. Smith
Photography Unit	Lt. Maynard Eicher (Navy)
Statistics and Records Unit	Capt. F. R. Lang (Navy)
Administration, Personnel, and Supplies Unit	CPhM C. E. Wagner

(3) Activities. Activities of this Section got underway rapidly following an important conference held in early January 1946 at the Naval Medical Research Institute at Bethesda, Md. These principal Army and Navy medical research agencies cooperated: Army Chemical Warfare Service (including the Biological Warfare Division), Army Medical Corps, Army Veterinary Corps, BuMed, Naval Medical Research Institute. Cooperation was promptly arranged also with the National Institute of Health of the U. S. Public Health Service, the

U. S. Department of Agriculture, the National Cancer Institute, the U. S. Geological Survey, and various universities and private research agencies.

The Section left San Francisco 1 June 46 on BURLESON. It placed its animals in the desired positions of exposure, recorded their conditions before and after each explosion, and then analyzed the injuries and investigated methods of diagnosis and treatment.

Public interest in the animals was so great that the Section Head was requested to participate in many of the press conferences.

6. DSM Electronics Group (014N).

(a) Function. This Group was responsible for determining, and in some instances, coordinating the determination of damage to electronic equipment exposed to the explosions.

(b) Organization. The organization of this Group is essentially identical to that of the 013D Electronics Group, described in Sec. 3.020.

(c) Activities. The Group exposed or assisted in exposing a wide variety of electronics and related equipment, made extensive inspections of damage, and analyzed and reported the results.

The Group was berthed on AVERY ISLAND.

7. DSM BuSandA (014S). A small group of BuSandA personnel assisted in exposing provisions, clothing, and other supplies.

8. DSM BuY&D Group (014Y). A small group of BuY&D personnel assisted in exposing a concrete drydock and two concrete barges. It was hoped that the damage data on the concrete structures would be adequate for showing the kinds and extents of damage which could be produced by an atomic bomb explosion near shore base installations.

E. Activities of DSM. The Director of Ship Material participated in the early staff meetings, organized his groups, maintained liaison with the Technical Director, and generally supervised the preparations of ships and exposed materials. He directed final preparations and inspections, and guided the preparation of reports. After each Test he entered the Lagoon with the Head of the Salvage Unit and directed re-boarding operations. After the extent and persistence of the B-Day radioactivity became apparent, he directed the decontamination activities. On his return to Washington, D. C. he supervised preparation of reports and recommendations, and disposition of vessels.

At Bikini R. Adm. Solberg was berthed on WHARTON.

3.022 Safety Adviser (015).

A. Designation. Captain G. M. Lyon (Navy) was designated Safety Adviser (015) to Commander JTF-1. Prior to the announcement of this designation on 1 Feb 46, he had been selected by the Surgeon General of the Navy, V. Adm. R. T. McIntire, to serve as special representative in the planning and execution of the Tests. Because of his previous close association with the atomic bomb project and his knowledge of chemical warfare, he was well qualified for such a task. He was assisted in his activities principally by Comdr. E. P. Harris.

B. Responsibility. As Safety Adviser, Capt. Lyon was a member of the JTF-1 Technical Staff and was responsible for preparing the Safety Plan (Annex E), selecting and instructing personnel in safety, and overseeing the execution of the Safety Plan. He cooperated closely in all phases of safety preparations with the Radiological Safety Adviser, Col. S. L. Warren (016), who was responsible for the protection of personnel from radiological hazards.

C. Activities. Captain Lyon was berthed on the MT MCKINLEY. His principal activities were the following:

(1) Before departing for Bikini, he prepared the Safety Plan, Annex E.

(2) During the week preceding Test A, he made each day predictions based on weather forecasts, as to what safety problems would arise if the bomb had been detonated on the particular day in question. He made corresponding predictions during the week prior to Test B.

(3) He participated in all major conferences with Commander JTF-1 and advised as to the new safety requirements arising from changes in the Operation Plan.

(4) On 12 Aug 46 he outlined to Commander JTF-1 a crash training plan for radiological safety monitors to complete the Operation. He was made Director of the training program.

(5) He organized the joint staff for the JTF-1 Radiological Safety School. Under his direction the staff prepared the training plan, wrote the curriculum, and selected the instructors. He helped to conduct the school from 6 Sept to 15 Oct 46.

(6) Captain Lyon returned to the United States on the SS HENRICO, arriving in Washington 30 Aug 46.

3.023 Radiological Safety Adviser (016).

A. Designation. Colonel S. L. Warren was designated Radiological Safety Adviser (016) in mid-January 1946. He was chosen for this position in view of his experience as Chief of the Medical Section of the Manhattan Engineer District. (He was on leave of absence from the University of Rochester's School of Medicine and Dentistry, where he is Professor of Radiology.)

B. Responsibility. His responsibility included making plans for avoiding injury from radioactivity, analyzing radioactivity data obtained, and deciding when it was safe for personnel to re-enter various parts of the target area and re-board the target vessels.

C. Activities. Colonel Warren was berthed on HAVEN. His principal activities were as indicated below. (Note: His activities as Head of the 013 Radioactivity Group are outside the scope of this Section. See Sec. 3.020.)

(a) He established the 0.1 roentgen daily limit of exposure of personnel to gamma radiation.

(b) Because of the precautions planned re gamma radiation, he decided that no special precautions were required re neutron radiation or other nuclear radiations.

(c) He assisted in the preparation of the Safety Plan, Annex E.

(d) He urged (on 11 Feb 46) consideration of the merits of using a different site for Test B; he felt that Test A might produce so much radioactivity -- and that this radioactivity would linger so long -- that postponement of Test B would be required. (However, Commander JTF-1 later decided that the danger of delay from this cause was not great enough to warrant preparing another site.)

(e) He advised on areas which would be radioactive, and on the evacuation of the inhabitants on Bikini and adjacent downwind islands.

(f) He advised on times of re-entry of various target areas and on times of re-boarding of the target ships.

(g) He advised keeping all support vessels at least ten miles away from Zeropoint during the A-Day and B-Day explosions, and he advised keeping all such vessels underway so as to facilitate any sudden shifts required to avoid radioactive air regions.

(h) He advised on procedures for decontaminating target vessels.

(i) He attended staff conferences and made tours of inspection.

3.024 Force Organization in General.

A. Introduction. The Joint Task Force, besides admitting of staff organization and technical organization, can also be described as a Force Organization, an organization of field operational groups.

B. Organization. Fig. 3.6 shows the Force Organization. It comprised a Commander (Vice Adm. W. H. P. Blandy), a Deputy Task Force Commander for Technical Direction (R. Adm. W. S. Parsons), a Deputy Task Force Commander for Aviation (Maj. Gen. W. E. Kepner), and eight individual task groups, designated 1.1 through 1.8. Each task group is composed of a number of task units abbreviated T. U. and each task unit is composed of a number of vessels.

Rear Admiral F. G. Fahrion was Commander of the advance echelon, i.e., the force organization existing prior to Vice Adm. Blandy's boarding the MT MCKINLEY.

The following pages list the 242 vessels which participated in the Operation, and then discusses separately each of the following eight Task Groups:

1.1 Technical Group
1.2 Target Vessel Group
1.3 Transport Group
1.4 Army Ground Group
1.5 Army Air Group
1.6 Navy Air Group
1.7 Surface Patrol Group
1.8 Service Group

C. Vessels. A total of 93 target vessels and 149 non-target vessels were used. These are listed below:

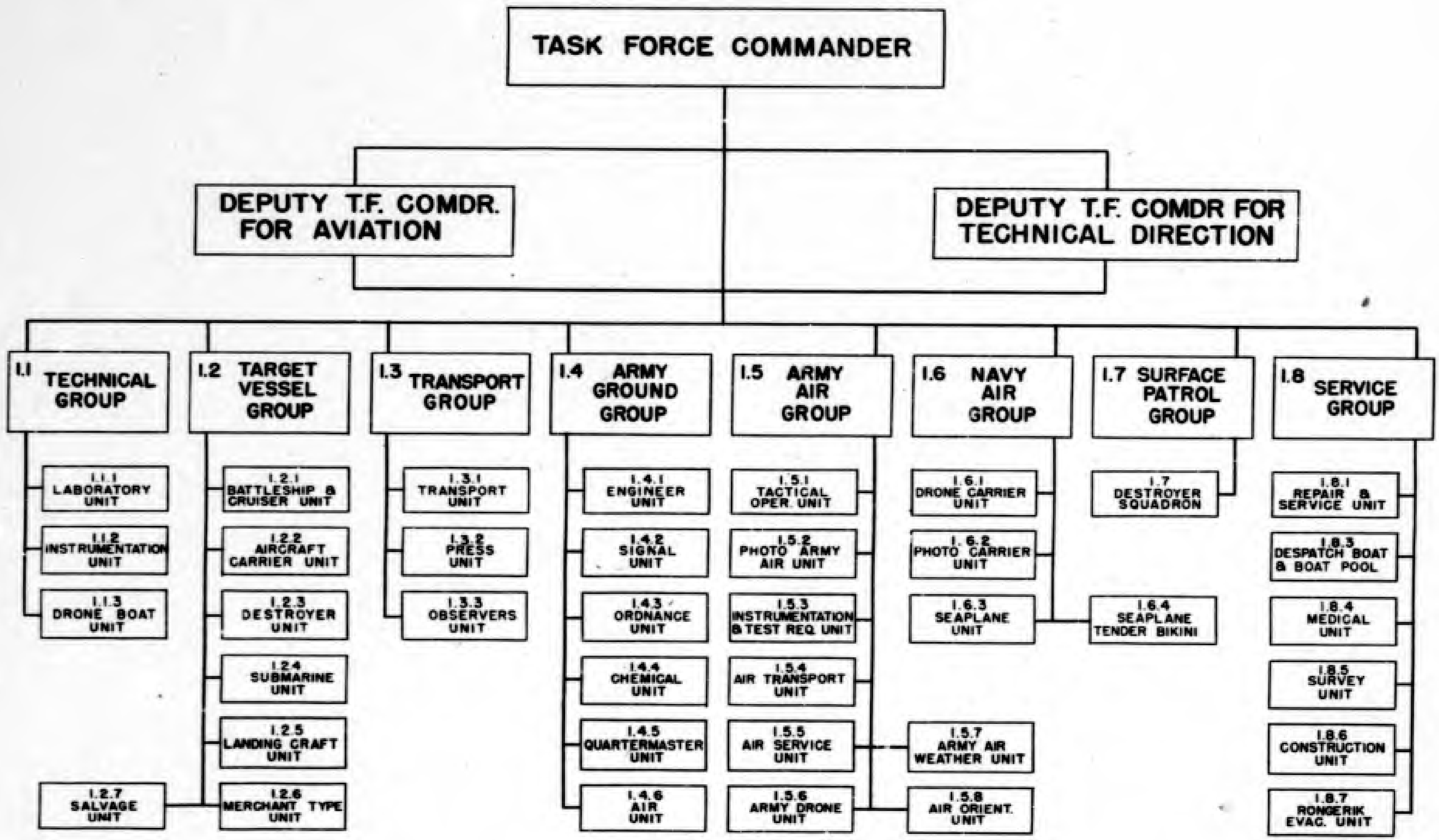


FIG. 3.6 FORCE ORGANIZATION

1. Target Vessels.

(a) Battleships and Cruisers.

ARKANSAS, BB-33
NEVADA, BB-36
NEW YORK, BB-34
PENNSYLVANIA, BB-38
PENSACOLA, CA-24

SALT LAKE CITY, CA-25

NAGATO, Ex-Japanese BB
SAKAWA, Ex-Japanese CL
PRINZ EUGEN, Ex-German CA

(b) Aircraft Carriers.

SARATOGA, CV-3

INDEPENDENCE, CVL-22

(c) Destroyers.

DD-367 LAMSON
DD-371 CONYNGHAM
DD-389 MUGFORD
DD-390 RALPH TALBOT
DD-402 MAYRANT
DD-403 TRIPPE

DD-404 RHIND
DD-406 STACK
DD-408 WILSON
DD-410 HUGHES
DD-411 ANDERSON
DD-413 MUSTIN
DD-419 WAINWRIGHT

(d) Submarines.

SS-184 SKIPJACK
SS-196 SEARAVEN
SS-203 TUNA
SS-305 SKATE

SS-308 APOGON
SS-335 DENTUDA
SS-384 PARCHE
SS-386 PILOTFISH

(e) Landing Craft.

LST - 52
LST - 125
LST - 133
LST - 220
LST - 545
LST - 661

LCI - 329
LCI - 327
LCI - 332
LCI - 549
LCI - 615
LCI - 620

LCT - 412
LCT - 414
LCT - 705
LCT - 812
LCT - 816
LCT - 818
LCT - 874
LCT - 1013
LCT - 1078
LCT - 1112
LCT - 1113
LCT - 1114
LCT - 1115
LCT - 1175
LCT - 1187
LCT - 1237

(e) Landing Craft. (cont'd).

LCM - 2
LCM - 3
LCM - 4
LCM - 5
LCM - 6
LCVP - 7
LCVP - 8
LCVP - 9
LCVP - 10
LCVP - 11
LCVP - 12

(f) Attack Transports (merchant-type construction).

GILLIAM (APA-57)
BANNER (APA-60)
BARROW (APA-61)
BLADEN (APA-63)
BRACKEN (APA-64)
BRISCOE (APA-65)
BRULE (APA-66)
BUTTE (APA-68)
CARLISLE (APA-69)
CARTERET (APA-70)
CATRON (APA-71)
CORTLAND (APA-75)
CRITTENDEN (APA-77)
DAWSON (APA-79)
FALLON (APA-81)
FILLMORE (APA-83)
GASCONADE (APA-85)
GENEVA (APA-86)
NIAGARA (APA-87)

(g) Concrete Drydocks and Barges.

YO - 160
YOG - 83
ARDC - 13

2. Non-Target Vessels.

(a) Force Flagship.

MT MCKINLEY (AGC-7)

(b) Target Vessel Control Group.

FALL RIVER (Flagship) (CA-131)

(c) Technical Group.

ALBEMARLE (AV-5)
KENNETH WHITING (AV-14)
CUMBERLAND SOUND (AV-17)
WHARTON (AP-7)
AVERY ISLAND (AG-76)
BURLESON (APA-67)
HAVEN (APH-112)
BEGOR (APD-127)
LCT-1359
LSM- 60

(d) Transport Group.

GEORGE CLYMER (APA-27)
BAYFIELD (APA-33)
HENRICO (APA-45)
APPLING (APA-58)
ROCKBRIDGE (APA-228)
ROCKINGHAM (APA-229)
ROCKWALL (APA-230)
SAINT CROIX (APA-231)
BOTTINEAU (APA-235)
BEXAR (APA-237)
ARTEMIS (AKA-21)
ROLETTE (AKA-99)
OTTAWA (AKA-101)
APPALACHIAN (AGC-1)
BLUE RIDGE (AGC-2)
PANAMINT (AGC-13)
LST-817
LST-881

(e) Navy Air Group.

CV-38 SHANGRI-LA
CVE-117 SAIDOR
AVP-49 ORCA
DD-834 TURNER
DD-835 C P CECIL
DD-882 FURSE
DD-883 N K PERRY

(f) Surface Patrol Group.

DD-368 FLUSSER
DD-692 A. M. SUMNER
DD-693 MOALE
DD-694 INGRAHAM
DD-722 BARTON
DD-723 WALKE
DD-724 LAFFEY
DD-725 O'BRIEN
DD-770 LOWRY
DD-781 R. K. HUNTINGTON

(g) Service Group.

DIXIE (AD-14)
COASTERS HARBOR (AG-74)
CHICKASKIA (AO-54)
SEVERN (AO-(W)-61)
ENOREE (AO-69)
TOMBIGEE (AOG(W)-11)
POLLUX (AKS-4)
HESPERIA (AKS-13)
AJAX (AR-6)
PHAON (ARB-3)
TELAMON (ARB-3)
CEBU (ARG-6)
CREON (ARL-11)
SPHINX (ARL-24)
FULTON (AS-11)
SIOUX (ATF-75)
CHOWANOC (ATF-100)
LIMESTONE (IX-158)
ARD-29
ATA-124
ATA-187
LST-388
LST-861
YC-1009
YF-385
YF-733
YF-734
YF-735
YF-752
YF-753
YF-754
YF-990
YF-991
YF-992

(g) Service Group (cont'd).

MUNSEE (ATF-107)
WENATCHEE (ATF-118)
WILDCAT (AW-2)
QUARTZ (IX-150)
YO-132
YO-199
YOG-63
YOG-70
YW-92

(h) Salvage Unit.

PALMYRA (ARST-3)
PRESERVER (ARS-8)
CURRENT (ARS-22)
DELIVER (ARS-23)
CLAMP (ARS-33)
CONSERVER (ARS-39)
RECLAIMER (ARS-42)
CHICKASAW (ATF-83)
ACHOMAWI (ATF-148)
WIDGEON (ASR-1)
COUCAL (ASR-8)
GYPSY (ARSD-1)
MENDER (ARSD-2)
ETLAH (AN-79)
SUNCOCK (AN-80)
ONEOTA (AN-85)
SKAKAMAXON (AN-86)
ATA-180
ATA-185
ATA-192
ATR-40
ATR-87
LCT-1184
LCT-1420

(i) Despatch Boat and Boat Pool Unit.

SAN MARCOS (LSD-25)
GUNSTON HALL (LSD-5)
PRESQUE ISLE (APB-44)
PGM-23
PGM-24
PGM-25
PGM-29
PGM-31
PGM-32
LCI-977
LCI-1062
LCI-1067
LCI-1091
LCT-1116
LCT-1130
LCT-1132
LCT-1155
LCT-1268
LCT-1341
LCT-1361
LCT-1377
LCT-1415
LCT-1461

(j) Medical Unit.

BOUNTIFUL (AH-9)
BENEVOLENCE (AH-13)

(k) Survey Unit.

BOWDITCH (AGS-4)
JOHN BLISH (AGS-10)
JAMES M. GILLISS (AGS-13)
YP-636
YMS-354
YMS-358
YMS-413
YMS-463

(1) Evacuation Unit.

LST-871

LST-989

3.025 Technical Group (T. G. 1.1).

This Group, commanded by R. Adm. W. S. Parsons berthed and otherwise assisted technical personnel. It consisted of three task units:

T. U. 1.1.1, the Laboratory Unit, had on board the groups which readied the bombs, transmitted timing signals, and prepared the "black boxes." It included ALBEMARLE, LSM-60, and LCT-1359.

T. U. 1.1.2, the Instrumentation Unit, included the great portion of the technical staff. Vessels included were: AVERY ISLAND, BURLESON, CUMBERLAND SOUND, HAVEN, WHARTON, and WHITING.

T. U. 1.1.3, the Drone Boat Unit, was responsible for operation of drone boats for determining radioactivity in contaminated areas. It included BEGOR and several LCVP drones.

3.026 Target Vessel Group (T. G. 1.2).

This group, commanded by R. Adm. F. G. Fahrion, was responsible for movements and care of the target vessels, including accurately positioning them for each test. Task Units 1.2.1 through 1.2.6 were responsible for: battleships and cruisers, aircraft carriers, destroyers, submarines, landing craft, and merchant type vessels, respectively. Task Unit 1.2.7 was responsible for salvage. FALL RIVER was the Task Group flagship.

3.027 Transport Group (T. G. 1.3).

This Group, commanded by Capt. W. P. Davis (Navy), was responsible for movements and care of various supporting transport vessels, including press and observer ships.

T. U. 1.3.1, the Transport Unit, included 9 APA's, 2 AKA's, and 2 LST's.

T. U. 1.3.2, the Press Unit, consisted of APPALACHIAN.

T. U. 1.3.3, the Observers Unit, consisted of BLUE RIDGE and PANAMINT.

3.028 Army Ground Group (T. G. 1.4).

This Group, commanded by Col. J. D. Frederick, was responsible for supporting the DSM Army Ground Group in the exposing of Army material to the atomic bomb explosions. Its six task units, 1.4.1 through 1.4.6, were Engineer Unit, Signal Unit, Ordnance Unit, Chemical Unit, Quartermaster Unit, and Air Unit.

3.029 Army Air Group (T. G. 1.5).

This Group, commanded by Brig. Gen. R. M. Ramey, was responsible for all operations of Army planes. It consisted of eight task units, based at Kwajalein.

T. U. 1.5.1, the Tactical Operations Unit, comprising 13 B-29's, furnished and flew the bomb-carrying plane, pressure gage planes, weather reconnaissance planes, and radiological reconnaissance planes.

T. U. 1.5.2, the Army Air Photographic Unit, comprising 9 F-13's and 2 C-54's, furnished and flew planes for aerial photographic coverage of the Tests.

T. U. 1.5.3, the Instrumentation and Test Requirements Unit, coordinated instrumentation programs of all Army planes obtaining physical data.

T. U. 1.5.4, the Air Transport Unit, comprising 10 C-54's, furnished and flew air passenger and freight planes and was prepared to evacuate personnel by air from Eniwetok Island to Kwajalein Island, should Eniwetok become endangered by the radioactive clouds resulting from the atomic bomb detonations.

T. U. 1.5.5, the Air Service Unit, was responsible for the servicing and repair of all Army planes.

T. U. 1.5.6, the Army Drone Unit, comprising 10 B-17 mothers and 6 B-17 drones, furnished, flew, and landed B-17 drone aircraft, an operation never before performed in history, for tasks including (1) collecting air samples of the radioactive cloud immediately following the detonation, (2) making blast pressure measurements, (3) taking photographs, (4) exposing aircraft in flight to the effect of the atomic bomb detonations, and (5) investigating effects on electromagnetic propagation.

T. U. 1.5.7, the Army Air Meteorological Unit, made a careful study of the velocity and direction of winds in the Bikini area and was responsible for weather predictions. It made daily weather reconnaissance flights from Kwajalein to the maximum range of the aircraft, each flight averaging 12 to 14 hours duration.

T. U. 1.5.8, the Air "Orientation" Unit, comprising 2 B-29's and 2 C-54's including "The Voice" and "The Eye," furnished and flew planes for the radio, press, and other observers.

3.030 Navy Air Group (T. G. 1.6).

This Group, commanded by R. Adm. C. A. F. Sprague, was responsible for operation of all Navy planes. It consisted of four task units.

T. U. 1.6.1, the Drone Carrier Unit, comprising 32 F-6-F mothers and 28 F-6-F drones, was responsible for operation of Navy drone planes. It included SHANGRI-LA and other vessels. Navy drone aircraft were flown to obtain filter samples of the radioactive cloud resulting from the bomb detonation, and to obtain photographs. Never before had unmanned planes been launched from carriers.

T. U. 1.6.2, the Photographic Carrier Unit, comprising 4 F-6-F's, 4 TBM's and 4 HOS's, was responsible for activities of Navy photographic planes, and two helicopters. It included SAIDOR and several other vessels.

T. U. 1.6.3, the Seaplane Unit, comprising 15 PBM's, was responsible for Navy patrol and air-sea rescue activities, and for the air-transport of personnel and freight between Bikini and Kwajalein.

T. U. 1.6.4, the Bikini Seaplane Tender Unit, provided seaplane facilities at Bikini. ORCA was the ship which serviced this Group.

3.031 Surface Patrol Group (T. G. 1.7).

This Group, commanded by Capt. E. N. Parker (Navy), was responsible for surface patrol, including the determination of the history of the air and sea regions contaminated with radioactive fission products. It also supported various other aerological and oceanographic technical activities, and helped in obtaining biological samples. It included approximately 9 destroyers.

3.032 Service Group (T. G. 1.8).

This Group, commanded by Capt. G. H. Lyttle (Navy), was responsible for a number of services, including repair, fuel, water, mail service, general supply, provisions, hospital and recreation, and evacuation of personnel from endangered islands.

It included these six task units:

T. U. 1.8.1 Repair and Service Unit
T. U. 1.8.3 Despatch Boat and Boat Pool Unit
T. U. 1.8.4 Medical Unit
T. U. 1.8.5 Survey Unit
T. U. 1.8.6 Construction Unit
T. U. 1.8.7 Rongerik Evacuation Unit

3.033 Preparation of the Operation Plan.

All principal operational plans approved by Commander JTF-1 during February and March of 1946 were combined and recorded formally in an Operation Plan officially designated as "Commander Joint Task Force One, Operation Plan No. 1-46 CJTF-1/A16-3; Serial 579." The Assistant Chief of Staff for Operations had the over-all responsibility for the preparation of the Operation Plan, including its annexes. A preliminary unofficial version of the Operation Plan was dated 20 Mar 46, and the final official version issued 15 Apr 46.

The Operation Plan proper consists of 14 pages; it first lists the Force Organization and the vessels used, and then lists the 29 Annexes, which are as follows:

Annex Symbol	Annex Title
A	Movement Plan
B	Logistics Plan
C	Communication and Electronics Plan
D	Security Plan
E	Safety Plan
F	Air Plan
G	Instrumentation Plan
H	Bikini Evacuation Plan
I	Re-entry Plan
J	Plan of Operation on A-Day
K	Plan of Operation on B-Day
L	Photographic Plan
M	Salvage Plan
N	Army Ground Group Plan
O	Public Information Plan
P	Target Layout Test A
Q	Target Layout Test B

R	Oceanographic Survey Plan
S	Harbor Information
T	Aerological Plan
U	Boat Pool Plan
V	Typhoon Plan
W	Ship Preparation Plan
X	Reboarding and Inspection Plan
Y	Air-Sea Rescue Plan
Z	Nonparticipating Observers Plan
AA	Rongerik Evacuation Plan
BB	Reports
CC	Drone Boat Plan

3.034 Activities Preceding Test A.

(For a chronology of principal events prior to Test A, see Appendix 1 to this History.)

(For a discussion of technical preparations for the Tests, see Part 3 of this History.)

Operations prior to Test A proceeded smoothly. The Bikini site was prepared, personnel and vessels were assembled and brought to Bikini, the target vessels were placed in the specified positions, instruments were installed, inspections were made, and the bomb-carrying B-29 Dave's Dream was readied without important mishaps.

A few unfortunate events occurred: A Navy enlisted man, R. L. Mangum, Seaman First Class, drowned on 25 Mar 46. Bacillary dysentery broke out on NEW YORK, AJAX, and TURNER. Two outbreaks of food toxication occurred. These outbreaks were quickly brought under control. (The sabotage which occurred on SAKAWA occurred before she came under command of JTF-1.)

The Queen Day rehearsal for A-Day came off very well. (Originally set for 25 June 46, and then advanced to 23 June 46, Queen Day was later postponed on account of bad weather until 24 June 46, Bikini local time.) Evacuation proceeded uneventfully. The dummy bomb was dropped, and "burst" at 0914. Re-entry proceeded according to plan.

Queen Day shortcomings were as follows:

(1) Certain timing signals, to be sent out just before How Hour on Queen Day by the 013 Los Alamos group, for the purpose of starting up various groups' instruments, actually were sent out considerably early. This, however, did not have important results.

(2) A number of small boats broke loose and were damaged, reducing the already tight supply of small boats.

(3) Heavy interference was produced by S-band (wavelength, 10-cm) and X-band (wavelength, 3-cm) radar on Television Channel No. 1.

(4) Spurious signals caused premature release of two drone boats, but the others operated properly.

(5) A fatal accident occurred on Kwajalein when Capt. J. E. Bishop (Army) was struck by the propeller of a B-29 which was warming up on the airstrip.

3.035 Activities from Test A to Test B.

(See later chapters for the executions of Tests A and B and for activities subsequent to Test B.)

After the A-Day bomb exploded at 0901 on 1 July 46 (Bikini local time) drone planes and boats made their runs, sampling the radioactive air and water. Photographic planes circled the area, photographing the damaged ships. Fire-fighting teams went into action. Safety inspectors, damage control groups, and JTF-1 Staff personnel boarded the target vessels, followed by damage inspection teams and observers. Instruments were recovered and analyzed. Film was taken to photographic laboratories (at Kwajalein or Washington, D. C., ordinarily), processed, and studied. Some repairs were made to damaged ships; various wrecked equipment was jettissoned.

In the following days, target vessels were relocated as required by the Test-B plan. APPALACHIAN made an interim trip to Pearl Harbor; PANAMINT and BLUE RIDGE made trips to Truk, Guam, and other islands; SHANGRI-LA returned to Roi. Some Army Air Forces personnel and some observers returned to U. S.

The most important event between Tests A and B -- the rehearsal on Test B 19 July 46 (William Day), -- was generally very successful, although marred by bad weather and premature detonation of the flash bomb. How Hour, originally announced as 0835 (Bikini local time), was postponed by Commander JTF-1 until 0905 in the vain hope that the considerable cloud coverage would lessen. Cloudiness prevented using the drone planes and all but a few of the patrol planes. Since an air rehearsal, which included all air units, had previously been conducted with success, the decrease in air activity did not detract appreciably from the success of the rehearsal. Spurious radio signals set off the M46 flash bomb prematurely, at 0814. Since the cameras were not set off prematurely, they failed to record the flash.

Three fatal accidents occurred between A-Day and B-Day: A Navy enlisted man, J. D. Moran, Radioman First Class, was accidentally electrocuted on 4 July 46 on ALBEMARLE; Lt. W. H. William (Navy) was killed on 9 July 46 in an airplane crash near Roi; a Navy enlisted man, J. R. Reagan, Seaman First Class, died as a result of methyl alcohol poisoning on 24 July 46.

A bundle of classified film (exact classification unknown) was stolen from (or lost by) an officer courier travelling from Binghamton, N. Y. to Washington, D. C., on 30 June 46.

The B-Day bomb was detonated at 0835 on 25 July 46 (Bikini local time).

3.036 Discussion of Staff Organization and Activities.

Staff functions were fulfilled without incident.

Personnel matters were handled with general success. However, these comments are pertinent: (a) There were shortages of electrical and electronics experts, radioactivity monitor personnel, divers, and certain other categories of personnel, (b) So many of the men left JTF-1 soon after their return to Continental U. S. that preparation of technical reports was hampered.

Security measures were generally effective. However, these comments are pertinent: (a) Approximately 20 persons were debarred, following routine security investigations, from participating in the Operation, (b) A bundle of classified film was stolen or lost (see Sec. 3.035); the control-record system — found to be inadequate for determining the identity or classification of the film — was immediately improved.

Public information activities were generally effective. (See Sec. 3.008 for an account of certain shortcomings of the A-Day Program.)

Operational planning and coordination were carried out without incident.

Logistics planning and coordination were handled without incident.

3.037 Discussion of Force Organization and Activities.

The Force Organization fulfilled its functions well. Both Tests were carried through on schedule. (Sections 3.034 and 3.035 describe several accidents which occurred before Test A and between the two Tests. A later chapter discusses the A-Day bombing miss.) YP-636 grounded on 13 Sept 45 and lost nearly all the preserved pelagic fish. (See Chap. 8.)

3.038 Discussion of Technical Staff and Activities.

The Technical Staff (013, 014, 015, 016) achieved its goals.

The Technical Director, whose responsibilities were perhaps of unexcelled variety and technical novelty, carried through his program with over-all success. Results of good reliability and adequate accuracy were obtained for all major phenomena of the explosions. These results were obtained even although a considerable number of instruments were rendered ineffective by (a) the A-Day bomb miss, (b) the A-Day timing-signal error, and (c) faulty performance of a number of the "black-box" instrument-starting devices. (These matters are discussed in a later chapter.)

The Director of Ship Material, whose group was by far the largest of all the technical groups, performed his varied and very extensive duties excellently throughout. When confronted (after Test B) with a contamination problem of far-greater-than-expected magnitude, his group, with the assistance of the 013 Radioactivity Group, quickly carried out effective decontamination measures.

The Safety Adviser and the Radiological Safety Adviser fulfilled their functions excellently; no one was injured by the explosions, and no one received any noteworthy overdose of gamma radiation. (See a later chapter.)

There is no doubt but that the vast technical program under the Deputy Task Force Commander for Technical Direction went through with general success. Technical execution on B-Day was almost flawless, and even on A-Day the several shortcomings did not prevent general achievement of all major goals.

3.039 Discussion of the Operation as a Whole.

The Operation was unique. Never before had 40,000 men taken part in a scientific test of such magnitude and importance, conducted in a remote spot thousands of miles from laboratories and institutions of learning. The scientific talent available was perhaps without precedent in a peacetime operation. The entire operation involved the closest integration of military, civilian, scientific and technical groups drawn from many sources.

Both Tests came off on schedule. A vast amount of information valuable to scientists, engineers, and strategists was amassed. The Army Air Forces, in the course of its extensive program of training and practicing for the A-Day drop, gained knowledge of new techniques and achieved reliability and precision never before attained. The Navy's major postwar problem, previously only vaguely defined, is now more clearly posed. A sound basis has been created for designing ships offering considerably increased resistance to the fury of the world's most powerful weapon, the atomic bomb.

Chapter 4

The Site

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The Site

4.001 Choice of Site.

The criteria used in selecting the site for the atomic bomb explosions are set forth in Sec. 1.002 and are not discussed further here.

The formal recommendation that the Lagoon of Bikini Atoll be used as the site was made on 21 Jan 46 by Commander JTF-1, and the Department of the Interior's Fish and Wildlife Service gave its endorsement to this choice of site on 23 Jan 46.

4.002 Map of Site; Code Names of Islands.

Fig. 4.1 is a map of Bikini Atoll, which contains 26 individual islands.

Because the earlier names of the islands making up Bikini Atoll were difficult to remember, pronounce, and spell, because they would have been very difficult to handle in dispatches, JTF-1 officially adopted (prior to 18 Apr 46) the following code names:

Earlier Name	Code Name
Airukiiji	Arji
Airukiraru	Airy
Aomoen	Amen
Arriikan	Aran
Bigiren	Biren
Bikini	Bikini
Bokoaetokutoku	Boku
Bokobyaadaa	Boby
Bokonejien	Bone
Bokonfuaaku	Bokon
Bokororyuru	Boro
Chieerete	Cherry
Eniairo	Enar
Eniirikku	Erik

Eninman	Eman*
Enyu	Enyu
Ionchebi	Ion
Namu	Namu
Ourukaen	Oruk
Reere	Reer
Rochikarai	Rokar
Romurikku	Romuk
Rukeji	Ruji
Uorikku	Uku
Yomyaran	Yoran
Yurochi	Yuro

4.003 Surveying the Site.

Since the only hydrographic chart of Bikini available when JTF-1 was created was a very inadequate chart of Japanese origin, a new survey was promptly ordered. BOWDITCH, SUMNER, and several other vessels (most of them from Task Unit 1.8.5) were given the job. Since ordinary sounding methods (and even recently-developed acoustical "bottom scanners") were not adequate for detecting and measuring bottom prominences known as coral heads, the wire-drag method was used most extensively. Depths were determined with especial care in the Lagoon entrance channels and in the areas to be occupied by target vessels and non-target vessels. Greatly improved maps were completed by the Navy's Hydrographic Office in Washington, D. C., and disseminated throughout JTF-1. (See a later chapter for an account of certain inadequacies even in those new maps.)

The survey unit erected many navigational markers on shore, in the entrance channels, and in the Lagoon proper.

The principal geographic fixes used at Bikini Atoll were beacons and benchmarks.

The locations of the principal beacons were as follows (according to the best -- but not final -- information available in the Technical Director's Office on 23 Oct 46):

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* This was later changed to "Prayer" to avoid confusion with "Amen."

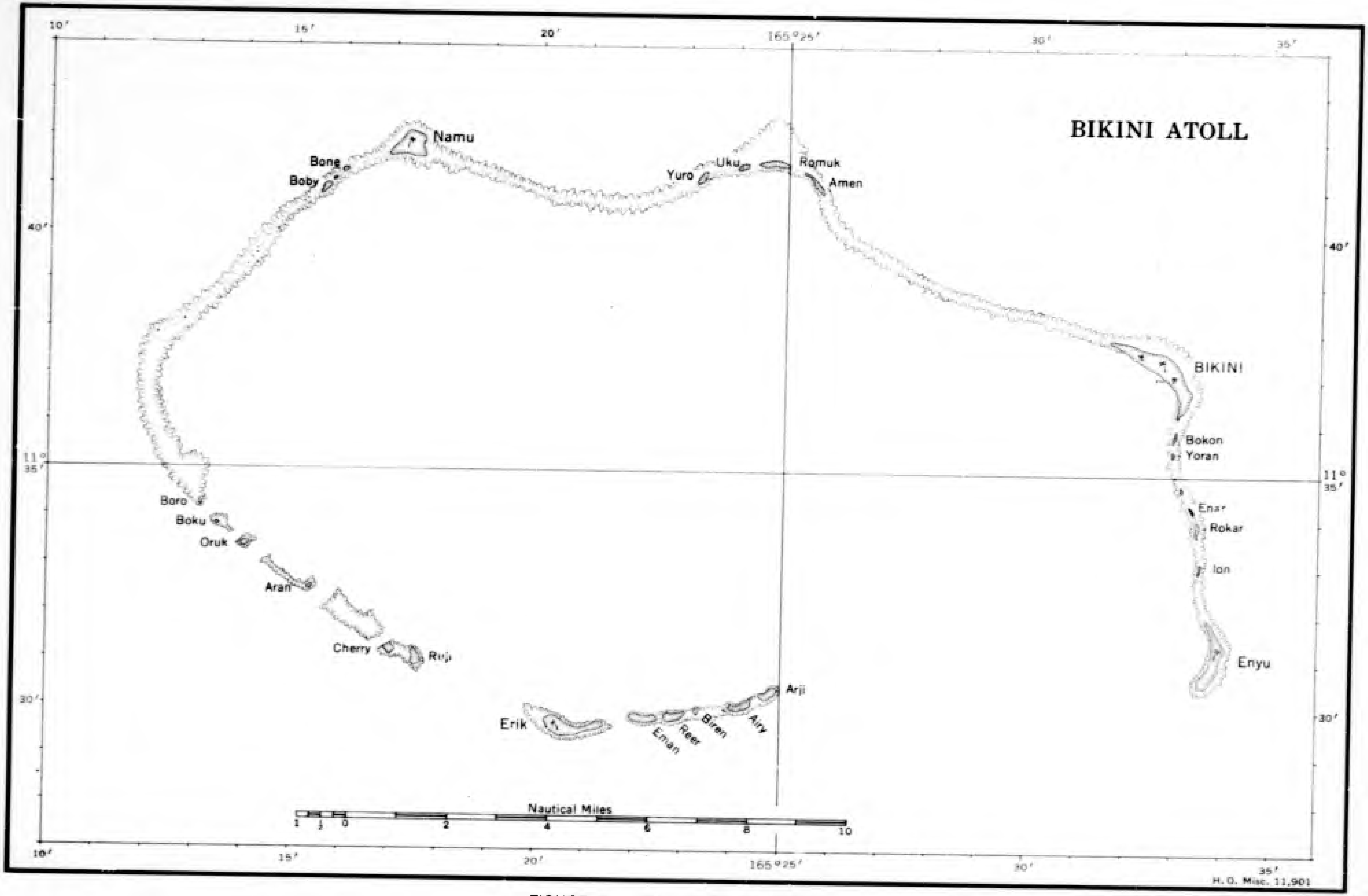

FIGURE 4.1—MAP OF BIKINI ATOLL

Beacon Symbol	Island on Which Beacon was Located	Latitude (Degrees, Minutes and Seconds)	Longitude (Degrees, Minutes and Seconds)
A	Enyu	11-30-42.6	165-33-32.6
B	Ion	11-33-03	165-33-31
C	Yoran	11-35-22.5	165-32-56.1
D	Bikini	11-37-02.9	165-32-46.0
E	Bikini	11-37-54.5	165-31-17.5
F	(a reef)	11-38-44	165-28-19
G	Amen	11-40-56.2	165-25-41.2
H	Arji	11-30-24.9	165-24-55.2
J	Erik	11-29-47.6	165-20-25.4
Beacon on North End of Enyu	Enyu	11-31-54	165-33-43.5

4.004 Removal of Coral Heads.

Obstructive coral heads were removed by dynamiting -- 100 tons of dynamite being used for the purpose. For the most part the coral heads were removed to accommodate deep-draft target vessels, or to permit the submerging of target submarines to the depths specified.

A considerable number of Japanese mines were located and removed. In September and October of 1945 Commander Marshall-Gilberts area (Task Unit 96.38.1) removed 35 mines. During March 1946, five more mines were removed by Commander Minecraft Pacific (Task Unit 18.11).

4.005 Preparation of the Moorings.

More than twenty moorings were prepared, primarily for securing those target vessels which were situated in the center part of the target array. In Test A, for example, over a dozen moorings, arranged in several parallel lines, were used to secure the central nine vessels. Each of these vessels was moored bow and stern and had a heading of approximately 085° True.

Approximately four moorings were prepared a short distance to the west of the target vessel array for use in securing any vessels which might break loose during the Tests.

A typical mooring consisted of a buoy, a riser chain, a clump, three 10-ton anchors, and three anchor chains. The clump was a 9 or

10-ton concrete block resting on the bottom of the Lagoon. It was attached to the three anchors by means of 500-ft chains. The riser chain connecting the buoy and the clump was made as short as feasible, to limit the swing of the attached target vessel.

Besides target-vessel moorings, several marker-buoy moorings were prepared.

4.006 Removal of Inhabitants.

In February, when it had been decided that Bikini Atoll was most suitable for the atomic bomb tests, the Navy Military Government Officer was directed to remove the natives of Bikini and their possessions to a place of safety prior to 15 Mar 46. In response to a request to assist in the interest of world peace, the inhabitants of Bikini, at a meeting of the Atoll Council, indicated a willingness to cooperate with the U. S. Government in the proposed experiment. Nine of the eleven alaps (family heads) named Rongerik Atoll, 128 mi east of Bikini, as their first choice for resettlement. Lajrwe, of Ailinglapalap, Paramount Chief of Rongerik, concurred in this proposal.

Naval construction battalion units with the help of 23 Bikini natives began construction work at Rongerik, clearing undergrowth and erecting prefabricated tent frames (26 structures - same number as on Bikini), canvas water tanks, six screened heads and nine (8 ft x 8 ft x 5 ft) concrete cisterns.

On 7 Mar 46 at 1700 Juda, the Magistrate, and 161 persons of Bikini departed on LST-1108 for Rongerik.

There has been some dissatisfaction and nostalgia among the natives; whether they will remain is questionable.

During the early summer, the natives of Rongelap, 85 mi east of Bikini, and Wotho, 92 mi south of Bikini, were moved to Lae, 145 mi south of Bikini, only for the duration of the Tests. Following the Tests, the natives returned to their homes.

In the possibility that Eniwetok might be in the path of the clouds from the explosions, all personnel who could be spared in advance of the Tests were evacuated by surface ship to Bascombe Island, Kwajalein Atoll, for the duration of the Tests. They were returned to Eniwetok 30 July 46.

On A-Day, remaining personnel on Eniwetok, not directly connected with Army drone plane operation, evacuated Eniwetok on a transport.

Later that night, they were given clearance to return.

On B-Day, similar precautions were taken. Eniwetok was alerted for evacuation at 1018; at 1418, the personnel returned to the Island.

The Bikini natives on Rongerik were evacuated the day before A-Day on LST-989. At 1002 A-Day after determining that the area of Rongerik was safe the natives were returned.

At Kwajalein all personnel not necessary for the A-Day last minute preparations were evacuated to Ebeye or to ships and boats in the Lagoon one day before A-Day.

4.007 Preparation of Land Installations.

Principal land installations prepared at Bikini Atoll included:

12	75-ft steel towers for mounting cameras and other technical equipment. (In view of high winds prevailing, these towers were constructed in horizontal position and then hoisted into vertical position.)
5	25-ft wood towers
12	20 ft x 20 ft steel huts
5	Seismograph huts
5	"Dead-man" moorings for Test C
6	Photography beacons, for aerial photography fixes
1	Club (20 ft x 20 ft) for 1000 officers and civilians
1	Club (16 ft x 300 ft) for 6000 enlisted men
5	Concrete basketball courts
10	Volley ball courts
4	Softball diamonds
1	Trap-shooting range
1	Concrete athletic court (100 ft x 100 ft)
26	Dressing huts
1	Water distillation and distributing system
1	Shore patrol and dispensary building
3	Life-guard platforms
1	Seaplane landing ramp
2	Swim floats
7	Pontoon causeways
1	Air-coordination station
3	Construction battalion shops

1 Sonobuoy work shop
10 Wave-height measurement piles
14 Shallow-water moorings for evacuation barges and other small craft
2 Radio beacons
5 25-man camps
1 Army aerological station

Construction activities were the responsibility of the Assistant Chief of Staff for Logistics and were carried out under the immediate supervision of his Construction Section (J-46). The work was performed by the 53rd Naval Construction Battalion acting through Task Unit 1.8.6.

The first group of the Construction Battalion to reach Bikini was a survey party, which arrived on 11 Mar 46. By 20 Mar 46 the entire Battalion had arrived; construction then progressed rapidly.

To reduce the insect nuisance, Bikini and Enyu Islands were sprayed every few weeks with DDT; Amen and Erik were sprayed once.

Preparations for the A-Day and B-Day evacuations included: removing the roofs of all buildings, moving construction equipment and portable causeways to a safe area, and securing generators and distillation plants.

4.008 Preparations at Other Sites.

At Kwajalein, which served as base for Task Group 1.5 (Army Air Group) and as principal staging point for air traffic and surface vessel traffic, special laboratories, some of them air-conditioned, were constructed for processing photographs, servicing blast gages, and analyzing post-explosion air and water samples to determine contents of fission products and unfished fissionable material. A pit, assembly hut, and ramp were constructed for assembling, handling, and loading Bomb A. Additions, improvements, and enlarging the facilities of Task Group 1.5 were made. These included an asphalt aircraft parking area, quonset huts for messing and billeting, ATC freight and passenger terminal, and additional electrical installations. A special fire-fighting system was installed; three pumps and several surface wells were located at strategic places along the runway in case of mishap to the bomb-carrying airplane.

Tidal stations and huts for seismographic equipment were constructed at Eniwetok, Kwajalein, Midway, and Wake.

Besides its radio stations at Bikini and Kwajalein, the 013 Los Alamos Group prepared stations at Roi and Eniwetok.

Relatively minor preparations were made at many other sites. (See Chap. 3.)

Chapter 5

Bomb Preparation and Plans

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Chapter 5

Bomb Preparations and Plans

5.001 Introduction.

The Joint Staff Planners recommended to the Joint Chiefs of Staff that an atomic bomb be detonated at each of the following altitudes:

(a) High in the air. (First priority)
(b) Immediately above or below the surface of the water. (Second priority)
(c) Deep underwater. (Third priority)

Because preparations for tests of types (a) and (b) could be completed within several months, these two types of tests were scheduled to be held during the spring and early summer of 1946. Although the deep underwater detonation (c) promised to cause at least as much structural damage as the other tests, the difficulties of submerging the bomb and determining its energy release made it clear that this test could not be held before 1947. (This test was later postponed indefinitely. See a later chapter.)

The general design of the bombs cannot be described here, although some remarks are included on fuzing and fins.

A detailed discussion is included of delivery and detonation of the bombs, since these matters greatly influenced the planning and execution of the Operation.

5.002 Bomb Design.

The bombs used were designed and built by the Manhattan Engineer District, and were of the Nagasaki bomb type, this being the most powerful type available.

The Test-A bomb contained a proximity-fuze system of extremely great reliability, sensitivity, and absolute accuracy. The fuze was set for an altitude of 515 ft.

In view of the presumptions voiced by some persons after Test A to the effect that Bomb A must have followed an anomalous descent (from an allegedly bent fin, lost fin, or cause unknown), the following facts regarding the bomb design are pertinent:

(a) During the war, dummy bombs of identical form, weight, and center of gravity were given extensive ballistic tests, and it was demonstrated that they were stable — with moderate safety factor. They were found to have no measurable wobble.

(b) The bomb-fin assembly was of box type, having no separate fins and no unsupported corners. The assembly was of all riveted construction. Heavy-gage metal was used throughout. The assembly was bolted to the bomb case with bolts providing a high safety factor. Even with several bolts removed, the safety factor would have been ample.

(c) In the several series of drop tests made during the war, using dummy bombs of identical size, shape, and weight, satisfactory flight was observed in all cases; none of the practice bombs tumbled or showed any wobble, spiral, or sail, and no significant ballistic errors were found.

5.003 Choice of Altitude and Depth of Detonations.

A. Choice of Altitude for Test A.

1. Introduction. At an important conference of JTF-1 and Manhattan Engineer District representatives on 22 Feb 46, the decision was made to detonate the Test-A bomb at 515 ft.

Because this choice of altitude exerted a far greater influence on the planning, execution, and results of Test A than any other single decision, the principal factors underlying the choice are discussed below.

2. High Altitude versus Low Altitude. Before the 515-ft altitude had been finally adopted, serious consideration had been given by R. Adm. W. S. Parsons, Dr. W. G. Penney, Sir Geoffrey Taylor, and others, to using a height of only 100 to 300 ft. This would have had many obvious advantages of accuracy and convenience, but the disadvantages appeared weightier. Crucial disadvantage was the expected reduction in effectiveness of the bomb explosion. Thus at the time under consideration (the time of the first few meetings of the LeMay Subcommittee), the majority of the principal theoretical-physicist advisers at Los Alamos and elsewhere were firmly convinced that the use of such altitude would reduce the explosion's effectiveness by a factor in the approximate range: 2 to 5. (It is now believed that the reduction in effectiveness would have been less drastic.) Other disadvantages of the lower altitude were: appreciable similarity to Test B, difficulty in constructing a high enough tower, difficulty in finding a suitable headland on which to place the tower, complications

introduced by reflections of the shock wave by the headland.

After discussion had become centered on a detonation in the range from 500 to 1000 ft and after it had been decided not to suspend the bomb from a blimp (see Sec. 6.004) but rather to drop the bomb from a B-29 plane, attention was focused on these two criteria: producing damage over the greatest possible area, and producing outright sinkings of innermost ships. It was estimated that a detonation at an altitude of 1000 ft would produce damage over an appreciably larger area than a detonation at 500 ft; but it appeared uncertain whether a detonation at 1000 ft would produce outright sinkings. The best compromise was believed to be in the neighborhood of 500 ft; a fuze adjusted for approximately 515 ft altitude was available, and accordingly this altitude was chosen.

3. Implications of Decision to Use High-Altitude Detonation. Discussed below are several potentially or certainly harmful consequences engendered by the decision to detonate Bomb A several hundred ft above the surface of the water -- a decision which implied (see Sec. 6.004) dropping the bomb from an airplane flying at approximately 30,000 ft.

(a) Target vessels and instruments could not be used with maximum efficiency. For it was necessary to assume that a bombing error would result and to adopt compromise target-vessel and instrument arrangements which, although not ideal for any one detonation position, would still be reasonably satisfactory for any detonation position within 1000 ft of the intended Zeropoint. (The compromise arrangements adopted are discussed in Chap. 6.)

(b) If a bombing miss greater than 1000 ft should occur (as unfortunately was the case), an appreciable amount of valuable data would never materialize. No substantial allowance was made in the instrumentation program, for example, for such a miss. And in the event of such a miss there was little chance that the detonation would occur near a battleship, cruiser, or carrier.

(c) The chance of carrying through the A-Day program on the desired date was reduced. To satisfy the bombardier's visibility requirements, especially clear weather over Bikini would be required. Good weather would be needed at Kwajalein also. The time required for the bombing plane to make practice runs lengthened the clear weather required. (Actually, the added stringency of the weather requirements played no appreciable part, since the weather was clear enough on the first day that the Task Force was ready for Test A.)

(d) Difficult-to-anticipate timing-signal problems were introduced (and, unfortunately, materialized). The bombing plane had to use radio to send the signal to operate the instrument-starting system. There was the possibility that errors -- electrical, mechanical, or human -- made in transmitting and receiving the signal would defeat the gathering of an appreciable fraction of the scientific data on the detonation proper.

(e) Accurate determination of positions and aspects of target vessels just prior to the detonation -- and thus accurate correlation of damage with direct effects -- was made difficult if not impossible. Because the vessels swung appreciably and continuously at their anchors and moorings, it was highly desirable that their positions be determined only a very few minutes or less prior to the detonation; yet the necessity of giving the bombing plane complete freedom of the air, as in the event of a wide miss, or a premature or delayed drop, meant that no photographic plane could fly above the target array just 5 min, say before How Hour. Thus reliance had to be placed on oblique shots from very remote planes and on horizontal shots from tower-based cameras. (Horizontal shots were unsatisfactory because the nearer target vessels obstructed the view of the farther ones. Cloud cover interfered somewhat with the photographs taken from the air.)

B. Choice of Depth for Test B.

1. Introduction. Early in May 1946, after prolonged consideration, the decision was made to detonate Bomb B at a depth of 75 to 100 ft.

2. Surface versus Underwater Detonation. Choosing between a surface detonation and an underwater detonation for Test B was difficult. The advantages and disadvantages of the alternatives were as indicated below:

(a) Advantage of Detonation at Surface. The bomb could easily be placed on a barge, no underwater suspension or underwater high-frequency transmission cable being required. Also, optical radiation, neutrons, and gamma rays emitted by the detonation would contribute to damage.

(b) Disadvantage of Detonation at Surface. A detonation at the surface would add little to what was learned in Test A. (See the foregoing Para. A, 2.) There was general agreement that relatively little of the energy would be transferred to the water and that very little underwater damage would be produced. Furthermore, a curtain of water would be thrown up by the pressure wave in water and would tend to shield the target vessels from the (slower-traveling) pressure wave in air.

(c) Advantages of Underwater Detonation. Interesting damage to target vessels would result from wave action, falling water, and of course, extremely high pressures exerted on the underwater parts of the vessels. Furthermore, the Lagoon water and the vessels themselves would be made highly radioactive and would remain so for a considerable period. Since this large-scale contamination would be potentially very harmful to ships' crews, a full-fledged investigation seemed called for.

(d) Disadvantages of Underwater detonation. Obviously, a special bomb container and complicated underwater rigging would be required for submerging the bomb. Also, timing circuits (including a watertight underwater coaxial cable) would have to be developed for the bomb in order to provide corroborative indication of the detonation efficiency. (Since little was known concerning the nature of transfer of energy from underwater-exploding atomic bomb to the surrounding water, it was essential to determine the explosion efficiency and, from this, the total energy release. For, if little damage were done, it would be difficult or impossible - lacking a knowledge of the amount of energy released - to determine whether the cause of the ineffectiveness was low-energy release or poor energy transfer.)

3. The final decision. The final decision to detonate the second bomb at 75 to 100 ft beneath the surface was made only after long discussions and successful dummy bomb submergence tests. During December 1945, for example, Commo. (now R.Adm.) W.S. Parsons urged an underwater shot; but several of the Manhattan Engineer District scientists and some other participating scientists, impressed with the various obvious difficulties, with the lack of time, and with the shallowness of the Lagoon (approximately 200 ft), recommended a surface shot. (They felt that detonating the bomb at any depth less than 600 ft would be only slightly different in effect from detonating it on the surface.)

Sentiment began to change in January and February of 1946. Many persons became increasingly aware of the embarrassing similarity which would exist between the surface shot and the air burst (Test A). Following an important conference on 22 Feb. 46 the Manhattan Engineer District scientists went very actively to work on detailed plans for an underwater shot (which now took on the status of formal alternative to the surface shot, despite reluctance of some JTF-1 groups to broaden their activities at such a late date.) By 28 Feb 46 encouraging progress had been made towards finding a way around the technical difficulties, and by 4 May 46 successful submergence tests had been completed at San Pedro, California, leading Commander JTF-1 to decide to concentrate solely on the 75 to 100 ft submergence plan.

C. Depth for Test C. The depth for Test C (indefinitely postponed on 7 Sept 46) had never been established. There had been two points of view, one favoring a depth of 1000 ft, the other favoring

1500 to 2000 ft. The principal difficulty in a deep sibmergence is the construction of a bomb container, a coaxial cable, and suitable stuffing boxes all capable of withstanding the extremely high hydrostatic pressures involved. (Contemporary subarine design, for example, permits submerging to depths of 600 to 800 ft with a safety factor of only 2.) Another limitation as to depth is imposed by the depth of the ocean in the area closely adjacent to Bikini Atoll, and by the desire (in order to avoid complications entailed by reflections from the bottom) to keep the bomb well above the ocean bottom.

In view of the postponement of Test C, no further details will be included here. (See, however, a later chapter.)

5.004 Choice of Delivery Method for Bomb A.

Having made the decision to detonate Bomb A at an altitude of 515 ft, Commander JTF-1 decided that the only feasible delivery method was to drop the bomb from an airplane. Suspension of the bomb from a blimp had been suggested, but was felt to present almost insuperable difficulties and hazards. The reasoning followed, in deciding to use the air drop, is made clear by the following quotation from the first draft of the JTF-1 Operation Plan:

> "Although greater accuracy of placement of the bomb for the air test might be achieved by suspending it from a blimp or other dirigible, the uncertainties and hazards of this method, including loss of the bomb in water, with consequent delay for recovery and reconditioning, make it undesireable. Furthermore, this is the only test of the three which can offer attack training to the Army Air Forces."

5.005 Preparations for Delivery and Detonation of Bomb A.

A. Selection of Bomb Carrying Plane. Delivery of Bomb A by air drop having been settled upon, the B-29, smallest common bomber capable of carrying an atomic bomb, was selected as the bomb carrier. The plane chosen, Daves' Dream, had been specially modified for carrying atomic bombs; its crew had been selected on the basis of competition among several specially-picked and extensively-trained crews.

B. Slection of Bombing Altitude. A bombing altitude of 30,000 ft was selected, this being the lowest altitude providing an ample margin of safety to the bombing plane and its crew. (It has been estimated that the minimum safe altitude for releasing an atomic bomb is 26,000 ft.) Flying at 300 m.p.h., the plane would release the bomb 16,500 ft from a vertical line through the actual Zeropoint.

C. Modification of Bombsight. In the attempt to insure better-than-normal bombing accuracy, a specially-modified Norden bombsight was used. Instead of providing the usual intersecting crosshairs, the bombsight provided for keeping the aiming point image between adjacent parallel crosshairs. The thickness of the crosshairs in the standard arrangement corresponds to an error of 400 ft when bombing from 30,000 ft.

D. Correction for Ballistic Winds. In a further attempt to insure high accuracy a ballistic-wind correction was made shortly before the drop. For this purpose supporting groups measured variations in wind direction and velocity in the air strata through which the bomb would fall.

E. Preparations for Detonation of Bomb A. Detonation of Bomb A was initiated by means of its proximity fuze designed to operate at an altitude of 515 ft. (See Sec. 5.002)

5.006 Plans for Determining the Energy Released by Bomb A.

A. Introduction. Unfortunately, no two atomic bombs can be counted on to release the same amount of energy. Although the two bombs used in Tests A and B were identical in construction to the Nagasaki bomb, it was expected that each might release a different amount of energy.

The term "equivalent TNT tonnage" is used in expressing the total amount of energy released in an atomic bomb explosion, although the equivalence, in some cases, is imperfect. An imperfection arises in attempting to equate energy derived from TNT to two or more kinds of energy, notably mechanical-damage-producing energy and radiant energy. Whereas TNT explosions do not give off any appreciable amount of radiant energy, atomic bomb explosions do. Before the Operation, some Los Alamos physicists made the estimate (not borne out by results at Bikini) that an atomic bomb explosion equivalent to 20,000 tons of TNT (i.e., one which liberates the same total amount of energy as would be liberated in exploding 20,000 tons of TNT) has "only" the mechanical-damage-producing potentiality of 12,000 tons of TNT, and emits radiant energy (e.g., energy of optical and gamma-ray radiation, and kinetic energy of neutrons) equal to the total amount of energy released by exploding 8,000 tons of TNT. (The explosion of 20,000 tons of TNT is usually taken to represent "by definition" a release of 8.4×10^{20} ergs.) However, results of the Tests indicate that -- at least in peak pressure methods of estimating the energy release -- the equivalence is far closer than had been thought.

Of the eight methods available for determining the amount of energy released by Bomb-A, six were used. At least one of the methods gave the total energy release ("mechanical" plus radiant energy) while others gave values for release of energy of certain limited manifestation only.

B. Methods for Determining Amount of Energy Released. Methods for determining the amount of energy released in Test A are discussed in some detail in various Los Alamos Laboratory reports, most of them being reports by O13-H. Only brief comments are included here.

1. Radiochemical Method. Principal reliance was placed in the radiochemical method for determining the (unqualified) total amount of energy released. The method involved determining (after the explosion) the ratio of abundance of (a) fission products and (b) fissionable material, in representative samples collected from the radioactive cloud and from the water. The number of fissions which had occurred in a given sample was determined either by measurement of the beta or gamma radioactivity of the fission products as a function of time, or by isolating individual specific fission products, which, of course, were formed in known relative yield, and (by means of usual radioactivity measurements) determining their individual concentrations. The amount of fissionable material present in the sample was then determined by measuring the alpha radioactivity -- either of the sample as a whole or of the fissionable material alone, i.e., after separation and purification.

From (a) the measured ratio of fission products to fissionable material in the sample, (b) the known weight of fissionable material in the bomb, and (c) the known energy release per unit weight of fissionable material actually fished, the total energy release was calculated.

Actually, the method of isolating and purifying the specific fission products and fissionable material before making the quantitative determinations was expected to be the most accurate of all the methods. Of course, the accuracy of this method was expected to be slightly reduced by normal delay in recovering samples from the radioactive cloud. A delay permits undesirable fractionation of fission products and fissionable material.

2. Peak-Pressure Method. The amount of "mechanical" energy released was determined from peak-pressure data. In this method, the best curve of peak pressure versus distance for Bomb A is compared with the corresponding curve for the Trinity Bomb. Theoretical equations available permit making a quantitative comparison of

energies.

3. Impulse Method. The impulse method is similar to the peak-pressure method, except that the former uses curves of impulse versus distance instead of curves of pressure versus distance. Impulse is, of course, the integral of pressure (psi gage with respect to time in seconds). Assuming perfect instrumentation, the impulse method has an advantage in that impulse is a more sensitive criterion of energy release than is peak pressure.

4. Shock-Wave Velocity Method. A so-called shock-wave velocity method of evaluating the "mechanical" energy release was used also. This method is closely related to the peak-pressure method, especially as shock-wave velocity is so very dependent on pressure.

5. Optical Radiation Method. The optical radiation method of determining the energy release consists of (a) measuring the volume and temperature of the ball of fire, (b) from those data computing the total amount of energy in the ball of fire. The volume in question is obtained by simple geometric computations based on photographs taken by high-speed cameras. Temperature of the ball of fire is determined with the aid of spectrographs and thermocouples and on the basis of the simplifying assumption that the ball of fire obeys Planck's Law of Black Body Radiation. Considerable corrections are required by absorption of the radiation by the intervening atmosphere.

6. Fire-Ball Growth Method. The fire-ball growth method of determining the greater part of the energy released (i.e. determining roughly the amount of energy transmitted by the shock wave in air) depends on measuring the rate of expansion of the ball of fire. By the use of Fastax or other high-speed cameras operating during the first 25 milliseconds after Mike Hour, the edge of the ball of fire, which at that stage (radius less than 125 meters) may be regarded as coinciding with the shock wave, can be followed readily, and the rate of expansion can be measured accurately. Theoretical considerations provide the equation from which the equivalent TNT tonnage of energy released in the shock wave may be calculated knowing only the values of shock wave radius at two arbitrary instants after Mike Hour.

7. Neutron Intensity Method. The neutron intensity method of measuring energy released was not effective at Bikini. However, brief mention of the method is desirable. By measuring the number of neutrons which are liberated in the detonation proper and which have energies greater than about 1.5 Mev it is theoretically possible to compare the energy release of an air-burst atomic bomb with that of the Trinity Bomb. The number of such neutrons may be determined by exposing samples of sulfur and observing the 14-day beta radioactivity of the P^{32} formed by the (neutron-proton) reaction in S^{32}.

This method is not a satisfactory one since neutrons are strongly attenuated by air. (The half-intensity path-length in air for neutrons emerging from the detonating bomb is about 200 yd, and very few of the neutrons travel more than 600 yd from the bomb.) Moreover the available attenuation data are extremely rough, particularly for ranges of several hundred yd.

8. Gamma-Ray Intensity Method. No great use was made of the gamma-ray intensity method of determining energy release. This method consists of measuring the integrated intensity of gamma radiation produced by the detonation proper and comparing the resulting value with values obtained from previous detonations (of known energy release). It is not a very reliable method since the gamma radiation is greatly attenuated by the air (the half-intensity path-length is in the neighborhood of 200 to 400 yd) and the attenuation varies considerably depending in unknown manner on the amounts of water in the air.

5.007 Preparations for Delivery and Detonation of Bomb B.

Bomb B was suspended from a landing ship (LSM-60), which had been extensively modified to provide rigging facilities, a laboratory, and special radio receiving and transmitting equipment. The bomb was contained in a strong, watertight, steel caisson; electrical communication was maintained with LSM-60 by means of conventional electric cables and also a special coaxial cable for transmitting ultra-high-frequency signals from the bomb to LSM-60.

The detonation of Bomb B was initiated by means of tone-modulated radio signals transmitted from the 013 Los Alamos Group's CUMBERLAND SOUND. The signals were coded to prevent accidental detonation by spurious signals. Multiple-channel operation was provided throughout the system to avoid detonation failure due to breakdown in any one channel.

Sensitive relays aboard LSM-60, operated by the tone-modulated signals, in turn, closed heavier relays which controlled the power supply to the arming and firing circuits of the bomb. In order to give remote indication of correct circuit operation, the relays also operated audio oscillators which provided repeat-back signals. These repeat-back signals modulated a VHF transmitter whose signals operated suitable panel lights on CUMBERLAND SOUND, 30,000 yd away. An additional repeat-back channel was provided to verify the closing of the arming voltage circuit.

5.008 Plans for Determining the Amount of Energy Released by Bomb B.

A. Introduction. Because the Test-B explosion occurred underwater, only two of the methods used for determining the energy released by Bomb A could be employed, namely, the radiochemical method and the peak-pressure method. The so-called gamma-ray timing method -- not feasible for an air-drop bomb such as Bomb A -- appeared to be eminently applicable as a rough check on the energy release of Bomb B; it would have been particularly useful in the event of a low-order detonation.

B. Radiochemical Method. As described in Sec. 5.007, the energy released by an atomic bomb may be determined by comparing, in samples of air and water near the explosion, the amounts of fission products and the amounts of fissionable material remaining unfished. In Test B particularly great reliance was placed in this method. Water samples were taken from the Lagoon as soon as possible after the explosion by means of drone boats. Also, large trays were placed on the decks of a number of target vessels to catch spray containing radioactive products.

C. Peak-Pressure Method. The underwater peak pressure values recorded in Test B were plotted against distance from the explosion. The resulting curve was compared with theoretical and experimental data for explosions of various known quantities of TNT; and the "mechanical equivalent" TNT tonnage of the Bomb-B energy release was thus determined. This method was somewhat complicated by bottom reflections of the pressure wave and by surface effects; bottom reflections were severe as a result of the shallowness of the Lagoon.

D. Gamma-Ray Timing Method. The gamma-ray timing method of determining the energy released by Bomb B was used mainly as a rough check on the other methods. The method was based upon the measurement of the time interval between two successive pulses, the first pulse being generated by the signal initiating the firing of the bomb and the second pulse being formed (in an ionization chamber located only a few feet from the bomb) by the gamma rays emitted during the detonation process proper. The two pulses were transmitted (with an accuracy of 0.2 microseconds) to CUMBERLAND SOUND (30,000 yd away) by radio equipment having very high frequency (video) modulation in order to handle the bandwidth required (i.e., to provide very high time-resolution). Line-of-sight propagation of the signals was insured by the use of transmitting antennas having considerable directivity and located at the top of an especially high mast; in receiving the signals, highly directional receiving antennas were used.

In order to prevent interference by pulses from radar sets situated in the area, a pulse coding operation was employed, each of the original pulses being transformed into a set of three separate pulses spaced at zero, three, and eight microseconds. By the use of special delay-circuits, the receiving system gave an output of just one pulse for each set of coded pulses received. The crucial datum -- the time interval between the two sets of coded pulses -- was determined by means of a common cathode-ray-tube radar technique.

One of the problems encountered in using this method for the underwater shot was getting the signals from the bomb (through a transmission line of considerable length) to the coding equipment and to the transmitting equipment without loss of time-resolution. The solution consisted of using, as transmission line, a coaxial cable, and placing at the input end of the cable a preamplifier, a pulse-lengthening circuit, and a heavy-duty cathode follower. This equipment was located near the bomb, i.e., inside the caisson, and was shielded by a 3-in. lead wall to block off the majority of the gamma radiation. There was believed to be a danger that this radiation would make the equipment inoperative before it had transmitted the second of the two crucial pulses.

5.009 Plans for Determining Positions of Target Vessels and Bombs.

A. Introduction. To permit accurate analysis of the scientific and engineering data collected during the Tests, it was important to determine the position and orientation of each target vessel with respect to the actual detonation points of bombs and it was desirable also to determine the absolute detonation points of the bombs themselves. Major reliance was placed on photography for making these measurements. A number of difficulties were anticipated, namely: change in target vessel position and heading between the time the overhead photographs were taken and Mike Hour; fogging of the film by gamma radiation; deterioration of photographic film due to high temperatures; concealment of the target arrays from photographic aircraft by cloud cover.

B. Methods for Determining Target Vessel Positions with Respect to the Actual Detonation Point of Bomb A. The plan-view distances of the target vessels from the actual Bomb A detonation point was determined by photographic survey. This method involved (a) triangulation, using photographs of the target vessels taken from tower installations on Bikini, Enyu, and Amen Islands and using island beacons and towers as fixed reference points; and (b) rectification of aerial survey photographs of the target arrays, again using island beacons and towers as fixed reference points. Method (b) was used partly to supplement and partly to corroborate method (a).

Tower photographs were taken as late as 30 sec prior to Mike Hour. The principal aerial survey runs were made 30 min prior to

Mike Hour. Other aerial photographs, not originally intended for survey work, were taken only a few seconds prior to the detonations and proved to be useful in the photogrammetric interpretation.

C. Method for Determining Target Vessel Orientations with Respect to Bomb A. The orientations of the vessels with respect to the Test A actual detonation point were determined from photographs and by studying flash burn patterns produced on the vessels and on special instruments (pyramidal orientometers) placed aboard the vessels.

D. Methods for Determining the Actual Position of the Bomb A Detonation Point. The vertical and lateral positions of the Bomb A detonation point were determined by photographic triangulation similar to that described above for locating target vessel positions. The altitude of the detonation point was obtained from photographs taken from towers on Enyu and Amen Islands.

E. Methods for Determining the Actual Position of the Bomb B Detonation Point. The position of detonation of Bomb B was taken to be directly under the well of LSM-60 from which the bomb was suspended. That is, the assumption was made that the bomb-carrying caisson was not swinging as from tidal current or motion of the ship. The position of LSM-60 was accurately determined by the photographic survey method discussed above.

F. Method for Determining Target Vessel Positions and Orientations with Respect to Bomb B. Target vessel positions and orientations with respect to Bomb B were determined by the photographic survey method discussed in the foregoing paragraph B.

Chapter 6

Planning the Target Vessel Array

Outline

Chapter 6

Planning the Target Vessel Array

6.001 Introduction.

Planning the target vessel array was one of the most interesting and most difficult phases of the Operation. The many factors which influenced the final decisions are considered in the following sections.

6.002 Factors Influencing Choice of Types of Target Vessels.

A. General Factors. In its directive of 11 Jan 46, the Joint Chiefs of Staff directed inclusion not only of captured vessels but also vessels representative of modern U. S. naval and merchant types. According to the earliest (unapproved) proposals, only captured vessels were to be used; but it soon became clear that the Tests would be much more valuable if vessels representing U. S. Naval construction were included. (The Chief of Naval Operations was apparently the first to propose that such vessels be included.)

Naturally, it was not feasible to include vessels of all U. S. Naval types -- especially the most modern types. However, it was expected that the information obtained from the exposure of a reasonably wide variety of vessels of modern type coupled with extensive scientific instrumentation would permit making reasonably reliable predictions as to what would have happened under similar conditions to other types of vessels -- present and future.

Principal structural differences between old and new vessels are: method of joining plates, and extent of compartmentation. Welding is now used instead of riveting. Although the older vessels have extensive subdivision, recent ships have more complete transverse watertightness to high-level decks and incorporate principles of longitudinal framing. At various times, additional watertight closures have been fitted in older vessels, but -- with no ships' crews present -- these closures are not ordinarily sufficiently tight to prevent gradual flooding. (Careful surveys made showed that many of the older vessels used -- although generally satisfactory for these tests -- were far below modern U. S. Naval standards of watertightness.) However, even a vessel of modern design and construction may have poor watertightness; the German heavy cruiser, PRINZ EUGEN, for example, although of modern all-welded construction, was found to have approximately the same watertightness as the older U. S.

cruisers.)

B. Specific Factors.

1. Introduction. The vessels selected as targets were largely those vessels -- over-age or of obsolete design -- which would otherwise have been decommissioned and sold for scrap. However, a modern aircraft carrier and several modern heavy-hulled submarines were included also.

In selecting the target vessels full consideration was given to the importance of including a wide variety of types of hulls, machinery, ordnance, aeronautical installations, and other equipment. the variety of vessel types is seen from the following list:

Type	Test A	Test B
Battleships	5	5
Cruisers	4	3
Aircraft Carriers	2	2
Destroyers	12	11
Submarines	8	8
Transports	19	17
Landing Ships	5	7
Landing Craft	30	34
Concrete Drydocks and Barges	3	3

2. Target Battleships. The target battleships included ARKANSAS, NEW YORK, NEVADA, PENNSYLVANIA, and the Japanese battleship NAGATO.

In general, the 4 U. S. battleships, although not of most modern design, possessed great resistance to battle damage. They had very heavy-hull construction, and torpedo-protection systems of multiple longitudinal bulkheads covering their vital spaces throughout 70 percent of their lengths. They had heavy side and deck armor and excellent subdivision; each had approximately 20 main watertight bulkheads, and also watertight decks and either a double or triple bottom. In each of these ships, the total number of watertight compartments, including tanks, was nearly 600. (A modern battleship of the IOWA class, for example, has approximately 900 watertight compartments. The construction of modern battleships includes a very heavy armor deck and upper side plating of special treatment steel for protection against bombs and fragments.)

3. Target Cruisers. The target cruisers included the U. S. cruisers, PENSACOLA and SALT LAKE CITY, the German cruiser, PRINZ EUGEN, and the Japanese light cruiser, SAKAWA. The U. S. cruisers and the SAKAWA each had an inner bottom extending up the side to somewhat above the waterline throughout the middle portion for

approximately 60 percent of the ship's length. The PRINZ EUGEN had double-hull structure along the bottom and three skins along the sides from the turn of the bilge to above the waterline. The PENSACOLA and SALT LAKE CITY, although old, were excellent examples of prewar riveted construction, with structure somewhat heavier than any cruisers up to the latest 8-in. cruisers built during the war. The PENSACOLA, SALT LAKE CITY, and the SAKAWA had two continuous decks throughout, the lower of these being armored. The PRINZ EUGEN had three continuous decks, the lowest of these being the protective deck.

Each of these cruisers had 15 to 18 main watertight-transverse bulkheads, designed to be tight to the second deck. In the ends of each ship forward and aft of the machinery spaces, two watertight platforms plus the transverse bulkheads formed additional compartments, which, including tanks, totaled between 200 and 250.

The PRINZ EUGEN was considerably larger -- and the SAKAWA was somewhat smaller -- than the U. S. cruisers. They represented the latest in cruiser design of Germany and Japan.

4. <u>Target Aircraft Carriers.</u> The target aircraft carriers selected were the SARATOGA and the INDEPENDENCE. The SARATOGA was originally designed more than 20 years ago as a large battle cruiser, while the INDEPENDENCE was to have been a sister of modern U. S. cruisers, mounting 6-in. guns.

Subdivision of the SARATOGA was unusually complete: she had approximately 1000 watertight compartments. There were 22 main transverse bulkheads and two continuous longitudinal bulkheads extended 70 percent of the length. Two watertight platforms extended fore and aft of the machinery spaces. The underwater protection was very similar in arrangement to that of modern battleships and large carriers. An inner bottom above the bottom shell was fitted between the innermost torpedo bulkheads for about 80 percent of the length.

The INDEPENDENCE had approximately 23 main watertight-transverse bulkheads carried tight up to the second deck. In addition to the main subdivisions thus formed, two watertight platforms in the ends of the ship further subdivided the ship into numerous watertight compartments. The ship had no main side-belt armor. An inner bottom inside the shell extended up to the deck for approximately 60 percent of the length. In addition to the shell and inner bottom, there were blisters port and starboard.

5. <u>Target Destroyers.</u> The 12 target destroyers, selected from the MAHAN, GRIDLEY, and SIMS Classes, were all of fairly recent design, commissioned 1936-1940. Their subdivision was good; the typical destroyer selected had approximately 75 watertight compartments and tanks. These ships had no torpedo bulkheading, no

inner bottoms, and, of course, no armor.

6. Target Submarines. Eight modern submarines were selected as targets. They were all of the "double-hull" design, with an inner-pressure hull and an outer hull not subject to water pressure when submerged. The two compartments at the ends of the ship were single-hull. Some of the target submarines were of the heavy-hull type, which have an inner hull of high-tensile steel plating 7/8 in. thick, as compared with the light hull submarines with medium steel inner hulls a little under 3/4 in. thick.

Because submarines are designed to withstand high hydrostatic pressures when submerged, they are capable of withstanding high pressures from not-too-close underwater explosions and in the past have demonstrated a remarkable resistance to depth-charge attack. Accordingly, the target submarines were considered to be excellent gages for these Tests, especially Test B.

7. Target Transport Vessels. The target transport vessels were all of the attack transport type (APA). They were typical of modern merchant-ship practice, with good transverse subdivision. Each had 11 main watertight tanks and compartments, but no watertight decks between the double bottom and the weather deck. The sides had only a single thickness of shell plating. These vessels were designed and built during the war and were essentially of all-welded construction, with very few riveted joints.

8. Target Landing Craft. The target landing craft included: landing ships, tank (LST); and landing craft, infantry (LCI); also smaller boats of open construction (LCT, LCM, LCVP).

The LST's had been specially designed for use in amphibious operation and their construction was considerably lighter than in recent merchant-ship construction.

The smaller landing craft were included in the Tests more for the purpose of determining the effects of wave action than for determining direct effects of pressure on the hulls.

9. Target Concrete Drydock and Barges. The concrete drydock and the concrete barges were included in the Tests for the purpose of determining the resistance of such modern reinforced concrete structures to the various effects of the bomb explosion. The inclusion of these types was prompted by results of a technical survey of the atomic bomb damage at Hiroshima and Nagasaki, where it was found that reinforced concrete structures were generally resistant to atomic bomb damage to a surprisingly high degree.

6.003 Factors Influencing Choice of Number of Target Vessels.

A. Joint Chiefs of Staff Requirement. The Joint Staff Planners of the Joint Chiefs of Staff, in setting up JTF-1, recommended that the number of vessels used be the maximum practicable in order to gain the greatest amount of useful information from each Test and in order to determine the complete relationship between ship damage and distance from the explosion. Necessarily then, a large number of ships was required. (Ninety-three target vessels were used in the course of the Tests.)

B. Allowance for Possible Bombing Error. The necessity of using in Test A a large target fleet was especially clear after it had been decided to drop the bomb from an airplane, i. e., after it was clear that there would be uncertainty as to the point of detonation.

C. Limitation Imposed by Congress. The Bill finally passed by Congress, (H. Con. Res. 307) authorizing the use of vessels as targets, limited the number of U. S. combatant vessels to 33, but did not limit the number of vessels of other types. (Originally, Commander JTF-1 had proposed the use of 3 captured vessels and 100 U. S. vessels, including 33 U. S. combatant vessels. Considerable public feeling developed to the effect that valuable vessels were going to be destroyed; Congress reacted by placing an upper limit on the number of U. S. combatant ships.)

6.004 Factors Influencing Choice of Target Vessel Locations.

A. General Factors.

1. Tactical versus Scientific Requirements. The Military Advisory Board to the Officer-in-Charge of the Atomic Bomb Projects, meeting with General Groves and JTF-1 representatives on 20 Jan 46, agreed that with suitable allowance for a reasonable bombing error, the ships should be placed in positions to provide the best instrumentation possible, rather than placed in a tactical formation. This policy was approved for both Tests.

This policy was a source of considerable public misapprehension. For some time the public failed to realize fully that the array selected represented neither a normal disposition at anchorage, nor a tactical disposition at sea, but rather an arrangement best fitted to satisfy the scientific requirements.

It was necessary to space the vessels closer together near the center of the array because of the rapid decrease of pressure in that area -- i.e., decrease of pressure with increase in distance from the Zeropoint. The early target arrays did not provide close central grouping: but in early January 1946 information obtained from previous atomic bomb tests became available to the effect that pressures would fall off more rapidly with distance than had been guessed initially. Thus, it now appeared that small differences in distance close to the Zeropoint would make considerable differences in the amount of damage. (However, there was a definite limit as to how many vessels could be concentrated near the center of the array, in view of the necessity for providing swinging clearances for vessels. To reduce this limitation, all vessels close to the Zeropoint were moored bow and stern.)

With such close grouping of the vessels, it was fully recognized that the total amount of damage inflicted would be greater than if the vessels were placed at normal distances from one another as in a typical fleet disposition. (The target array for Test A contained 24 vessels located 1,000 yd or less from NEVADA, the intended Zeropoint. In Test B, 21 vessels were placed within the same area. A fleet at anchorage would typically contain 4 to 7 vessels within a circle of 1000-yd radius, and in the case of a fleet at sea, the same area would probably not include more than one capital ship.

2. Graded Damage Requirement. The Joint Chiefs of Staff's directive to Commander JTF-1 laid down the general requirement that the target vessels be disposed in a manner calculated to give a gradation of damage from maximum to minimum. This involved dispersing the target fleet so that individual ships of each major type would be placed in positions ranging from close to the Zeropoint (for major damage) to appreciable distances from the Zeropoint (for light damage).

Ideally, to secure maximum information on graded damage, it would have been desirable (1) to include identical vessels exposed at different distances from the Zeropoint so that straight-forward correlations could be made between damage and distance; and (2) to provide two lines of vessels of given type, one line being composed of vessels broadside to the Zeropoint and the other composed of vessels bow-on or stern-on, to show the effect of orientation. This general geometric scheme was followed for those types of vessels comprising large enough numbers of vessels -- that is, for attack transports (APA's), destroyers (DD's), and landing craft (LST's, LCI's).

Vessels of each of these three types were berthed at regular intervals along a single, somewhat curved, line extending more or less radially from Zeropoint. Curvature of the lines served, of course, to prevent any one vessel from shielding its successors.

B. Chronological Factors.

1. Introduction. Before the target arrays for Tests A and B were finally determined, approximately 19 different target arrays had been proposed. The arrays finally approved by the Joint Chiefs of Staff represented compromises between the arrays proposed by representation of JTF-1, by the Army Air Forces, and by the Military Advisory Board to the Officer-in-Charge of the Atomic Bomb Project.

The positions of the target vessels given in the following discussions are approximate only. (Changes in wind direction and velocity caused considerable shifting of positions from hour to hour; even moored ships were subject to some movement and changes in heading.) The true final positions at the A-Day and B-Day Mike Hours are given in later chapters.

2. Test-A Target Array.

(a) The First Plan. The first target array proposal for Test A was made in December 1945, before JTF-1 had officially come into existence. It was prepared by BuShips representatives and was based on knowledge of the ships which probably would be available for the Tests, the characteristics of those ships, and rough estimates of the damaging effects of 20,000 tons of TNT based on war experience. The Zeropoint was located 5000 yards from Bikini beach. The aircraft carrier, RANGER, was placed at 1000 yards from Zeropoint. NEW YORK, ARKANSAS, and one submarine were placed at 1500 yd. With the exception of a number of destroyers and victory ships, all other vessels were at greater distances.

(b) Intermediate Plans. The original plan -- prepared without detailed knowledge of the pressure-distance relationship to be expected -- underwent early and drastic revision. The revised plans called for closer grouping near the center and moving the center of the array closer to Bikini Island. Closer grouping of the vessels near the center was necessitated by the possibility of a bombing error and by the implications of the pressure-distance relationship discussed under Paragraph A of this Section.

Considerable discussion was focused on the implications of a possible bombing error. Army Air Forces spokesmen (for example, Lt. Gen. I. C. Eaker, Deputy Comdr. of the Army Air Forces) pointed out that while it was expected that a skilled bombing team could with a high degree of assurance place the bomb within 500 ft of the Zeropoint, the possibility of mechanical or other malfunction, however slight, must be considered. It was therefore decided to adopt closer spacing of vessels in the central area to guarantee that even in the event of an error of 1000 ft, the success of the Test would not be appreciably jeopardized. (Maj. Gen. W. E. Kepner, at the 29 Jan 46 meeting of the Military Advisory Board to the Officer-in-Charge of the Atomic Bomb Project, suggested that vessels be placed so as to allow for a 300-yd radius bombing error.) The Army Air Forces spokesmen requested filling up the gaps in the array within 1000 ft of the Zeropoint and providing circular symmetry about the Zeropoint. For the most part, the Army Air Forces' proposals were adopted. Dr. W. G. Penney and Sir Geoffrey Taylor suggested that the major combatant vessels within 800 yd of the Zeropoint be arranged in a concentric pentagonal array.

In view of the limited number of target vessels available, it was considered necessary to assume that the bombing error would not exceed 1000 ft. Thus, outside the 1000-ft circle a number of gaps in the array were permitted. For example, a gap existed in the vicinity of GILLIAM.

(c) The Final Plan for Test-A Target Array. The center of the target array was located approximately 5400 yd from Bikini Beach. (A closer location was not permissible due to shallow water and occasional coral heads.)

To permit the densest array possible within 1000 yd of the Zeropoint, vessels within the 500-yd circle plus ARKANSAS and SALT LAKE CITY at about 600 yd were moored bow and stern. Because of mooring difficulties, including limited supply of ground tackle, vessels other than the above were secured only by anchors.

Dispositions of vessels of different classes are considered below, starting with battleships. References to "Zeropoint" refer, of course, to the intended projected Zeropoint — the surface point directly below the expected detonation point.

(1) Battleships. The NEVADA was selected as the central battleship because she was the most rugged ship available. (The aircraft carriers, RANGER and INDEPENDENCE, and the battleship,

PENNSYLVANIA, each had previously been considered as the central target ship.) Four other battleships, including one captured battleship, were positioned broadside at 300, 600, 1200 and 1500 yd from the Zeropoint.

(2) Cruisers. One U. S. and 1 captured cruiser were placed broadside to the Zeropoint at 300 yd. One other U. S. cruiser was anchored at 600 yd.

(3) Aircraft Carriers. Only 2 aircraft carriers were included in the target array. These were a light aircraft carrier at 300 yd and a heavy carrier at a little over 2000 yd. It was not expected that the heavy carrier would sustain much damage at this distance; it was planned that she would be a principal target in Test B.

(4) Destroyers. Eight of the 12 target destroyers were deployed (broadside) in two lines on opposite sides of the Zeropoint, one line extending from 750 to 2600 yd, the other from 1750 to 2100 yd. In addition 3 destroyers were placed at 300, 500, and 750 yd. The remaining destroyer was placed at approximately 2 mi.

(5) Submarines. Eight target submarines were used. Light-hulled and heavy-hulled submarines were placed in pairs at 1000, 1500 and 2000 yd from the Zeropoint. In addition, one heavy-hulled submarine was anchored at 1500 yd. It was hoped that the pairing off of light and heavy-hulled types would supply information on their relative resistance to damage. All of the submarines were surfaced so they could be exposed to the full force of the explosion.

(6) Attack Transports. Nineteen attack transports (APA) were anchored in two principal (curved) lines. One of the lines extended from 700 to 3200 yd from the Zeropoint and the other from 800 to 3700 yd. The attack transports in one line were broadside and those in the other line were bow-to.

(7) Landing Craft. Approximately 30 landing craft were used. Four LST's were placed in a line extending from 1500 to 4000 yd from the Zeropoint. A line of 6 LCT's extended from 875 to 4000 yd in the direction of Bikini Island. Four LCI's were anchored in a line 1800 to 4000 yd from the Zeropoint. In addition, 4 LCT's, 5 LCM's and 6 LCVP's were placed at approximately 200-yd intervals along Bikini beach.

(8) Concrete Barges. To determine the damage resistance of reinforced concrete ships at close range, a concrete floating drydock was placed 800 yd from the Zeropoint, a concrete oil barge was placed at 500 yd and another concrete barge was placed at 1000 yd.

3. Test-B Target Array.

(a) Comparison between Test-A and Test-B Requirements.

(1) In Test B the majority of the submarines were to be submerged since this Test was expected to produce its greatest pressure beneath surface of the water, and since submarines are the most pressure-resistant of ships, the results on submerged submarines were expected to be especially important.

(2) Since the fixed position of the Bomb in Test B would eliminate uncertainty such as had been expected with respect to position of detonation of Bomb A, and since there was little prospect that ships within 500 yd of Bomb B would survive, far fewer ships were required in the central area for Test B.

(b) The Final Plan for Test-B Target Array.

(1) Battleships. Five battleships (including 1 captured battleship) were placed at 200, 800, 1000, 1200, and 1400 yd from the Zeropoint. (In the early Test-B target arrays, the nearest battleship had been placed at 300 yd from the Zeropoint. The Commanding General of the Manhattan District urged that this distance be decreased to 200 yd to make sure that serious damage would result, and his proposal was accepted by the Joint Chiefs of Staff.)

(2) Aircraft Carriers. Two aircraft carriers were employed, the SARATOGA at 500 yd from the Zeropoint and INDEPENDENCE at 1400 yd. (There had been much discussion as to the best position for the SARATOGA. Early arrays placed her at 300 yd from the Zeropoint. Then in the light of Dr. W. G. Penney's estimate of 500 to 700 yd as the lethal radius for the underwater explosion, it appeared that at 300 yd the SARATOGA would probably sink so rapidly that no photographs could be made of the behavior of her flight deck under the severe hull pressure and wave action expected. The Evaluation Board recommended moving her out to 500 yd, and the Joint Chiefs of Staff approved. Actually, because of slack mooring and change in wind direction on B-Day, SARATOGA's position at Mike hour was considerably closer to the Zeropoint than had been intended. (See a later chapter.)

(3) Cruisers. Two cruisers were intended to be exposed broadside to the explosion, one at 700 yd and the other at 1200 yd.

(4) Destroyers. Eight destroyers were placed broadside along a curved line. They were located at distances ranging from 750 to 3500 yd. Three other destroyers were positioned end-on to the explosion at 700, 1250, and 1750 yd.

(5) Submarines. Of the 8 submarines exposed, two pairs, (1 light-hulled submarine and 1 heavy-hulled submarine in each pair) were exposed broadside to the explosion at 800 and 1300 yd. One heavy-hulled submarine was placed 300 yd from Zeropoint, end-on, and two others of the same type were positioned broadside at 750 and 1500 yd. A light-hulled submarine was placed broadside at 1800 yd. Six of the submarines were in submerged positions.

(6) Attack Transports. In all, 17 attack transports (APA) were exposed in two curved lines extending outward from the Zeropoint, the ships in one line being end-on at 500 to 3700 yd and the ships in the other being broadside at 700 to 3200 yd.

(7) Landing Craft. In all, 33 landing craft were exposed. Four LST's were placed broadside in a single line extending from 1600 to 4100 yd from the Zeropoint. One LST was exposed end-on at 750 yd. Another LST was placed on Bikini beach. A line of 5 LCT's and a line of 4 LCI's were arranged at distances of 2000 to 4000 yd from the Zeropoint. In addition, 4 LCT's, 6 LCM's, 6 LCVP's, and 2 LCI (L)'s were exposed at approximately 100-yd intervals along the beach. (The exposure of landing craft near the beach was intended to show the effects of the wave action on a simulated amphibious landing operation.)

(8) Drydock and Barges. A floating concrete drydock was positioned 1200 yd from the Zeropoint and 2 concrete barges were placed at 800 and 100 yd.

6.005 Factors Influencing the Choice of Fuel and Ammunition Loadings.

A. Introduction. In the entire Operation there were few subjects more controversial than the best fuel and ammunition loadings for the target vessels. The principal arguments are presented below:

B. Argument in Favor of Loadings Representative of Service Conditions. The Army Air Forces initially took the position that in order for the Tests to be realistic, the target vessels should carry the same fuel and ammunition loads they would carry in normal wartime service. In this way, information could be secured on damage caused by burning fuel and exploding ammunition as well as damage caused by the immediate effects of the bombs. It was felt that whether a vessel was destroyed by the bomb or by subsequent secondary damage was not important, if under actual conditions it would have been destroyed by either. The Air Forces position was at first supported by the Commanding General of the Manhattan District who later agreed to using limited fuel loadings.

C. Arguments in Favor of Token Loadings.

1. Preservation of Scientific Values. The JTF-1 Technical Director opposed adoption of full fuel and ammunition loadings on the grounds that many instruments and records aboard ships might be destroyed by secondary fires. He stated that the Tests were not intended to be tests of fleets, convoys, or task forces, but rather of individual vessels. Furthermore, token fuel and ammunition loads would be adequate for showing whether magazines were disposed to explode, whether oil tanks would be ruptured or fuel set on fire.

Even after the fuel and ammunition loadings had been determined to the satisfaction of the Military Advisory Board, the Army Air Forces, and JTF-1, an appreciable change was proposed by Dr. K. T. Compton, Chairman of the Joint Chiefs of Staff's Evaluation Board. He proposed that there be no oil and gasoline loading, and perhaps no ammunition loading, on those vessels located in the upwind 90° or 120° sector of the array. He feared that fires originating in this sector might spread and thus might destroy many instruments and records and might hamper the collecting of samples of contaminated water.

2. Preservation of Primary-Damage Information. In order to prevent confusion in distinguishing primary damage from secondary damage, the Director of Ship Material proposed that only a few of the target vessels' fuel tanks be filled, and that in general, gasoline and oil loadings be reduced to the absolute minimum. He recommended also that only a small number of samples of high explosives be used, these to be placed at various distances from the Zeropoint and to be located in such a position (on each vessel concerned) that danger of serious damage to the vessel as a whole would be negligible.

3. Minimizing Danger to Personnel. The Surgeon General of the Navy considered that the loading of fuel and ammunition (on any single target vessel) in excess of 10 percent of the normal full load would create an unjustifiable hazard to personnel returning to the target area. The Bureau of Ordnance took a similar stand, pointing out that there was a serious shortage of bomb-disposal officers and that the danger from delayed ammunition explosions would be serious if more than token ammunition loadings were attempted.

D. Criteria for Loadings Finally Adopted. The Military Advisory Board to the Officer-in-Charge of the Atomic Bomb Project, meeting with JTF-1 representatives on 19 Feb 46, set down the following criteria which were recommended by Vice Adm. Blandy and approved by the Joint Chiefs of Staff and used in determining the actual ammunition and fuel loads.

1. Fuel Loadings for Test A. Vessels within 500 yd of the

Zeropoint carried fuel loads ranging from minimum (approximately 10 percent of normal) to 33 percent of normal load. "Normal" load is defined as the normal service allowance, or 95 percent of capacity. Vessels 500 yd or more from the Zeropoint were loaded with fuel as follows: 1/3 of the vessels of each type carried the minimum fuel load: 1/3 carried 50 percent of normal and the remaining 1/3 carried normal load. The fuel loads were so distrubuted that all vessels in the upwind 120° sector (015° to 135°) and within 2500 yd of the Zeropoint had minimum fuel loads except the HUGHES and NAGATO which carried 15 percent of the normal fuel load, and the submarines which carried normal fuel loads.

2. Ammunition Loadings for Test A. Vessels within 500 yd of the Zeropoint carried ammunition loads ranging from minimum (approximately 10 percent of normal) to 2/3 of their normal load (approximately 95 percent of capacity). Vessels outside of 500 yd from the Zeropoint carried ammunition loads as follows: 1/3 of the vessels of each type carried 10 percent of their normal load: 1/3 of each type carried 50 percent of their normal load: and the remaining 1/3 carried normal load. All vessels in the upwind 120° sector (015° to 135°) and within 2500 yd of the Zeropoint had minimum ammunition loads except the NAGATO, which carried merely a sample of ammunition, the HUGHES which carried 67 percent of normal load , and three submarines which carried normal ammunition loads. All ammunition loads included only ammunition of U., S. make.

3. Fuel Loadings for Test B. Vessels within 500 yd of the Zeropoint carried fuel loads ranging from minumum load to normal load. Vessels in the upwind 100° sector (040° to 140°) and within 2000 yd of the Zeropoint had minimum fuel loads except the HUGHES which carried 15 percent of normal fuel load and the submarine PILOTFISH (submerged)which carried a normal fuel load. Fuel loadings on vessels outside of 2500 yd were distrubuted in approximately the same manner as in the similar area for Test A.

4. Ammunition Loadings for Test B. Vessels within 500 yd of the Zeropoint carried ammunition loads ranging from 50 percent of normal to normal load. Vessels in the upwind 100° sector (040° to 140°) and within 2500 yd of the Zeropoint had minimum ammunition loads except the HUGHES which carried 67 percent of normal ammunition load and the submarine PILOTFISH (submerged) which carried a normal ammunition load. Ammunition loadings on vessels outside of 2500 yd were distributed in approximately the same manner as in a similar area for Test A.

6.006 Factors Influencing the Orientation of Target Vessels.

Wherever the number of target vessels permitted, vessels of a given type were placed broadside, bow-to, and stern-to, with respect to the Zeropoint. Because of the small number of large combatant vessels available for the Tests, these ships were given the orientation believed to afford greatest vulnerability, i.e., broadside orientation.

Chapter 7

Technical Preparations for Determing Damage to Vessels.

Aircraft and Material

Outline

Chapter 7

Technical Preparations for Determining Damage to Vessels, Aircraft and Material

7.001 Introduction.

To handle the enormous job of determining damage to vessels, aircraft, and material, the Deputy Task Force Commander for Technical Direction set up a special group called Director of Ship Material Group, headed by R. Adm. T. A. Solberg. The exposure of Army material, although included in the responsibilities of the Director of Ship Material, was under the immediate supervision of Col. J. D. Frederick. The drone-plane exposure program was under the supervision of the Deputy Task Force Commander for Aviation, Maj. Gen. W. E. Kepner.

The Director of Ship Material divided his technical preparations into two phases: (1) Readying (2) Inspection. Under Readying he included all activities incident to preparing the target vessels and material for the Tests. Under Inspection he included all activities incident to determining and recording the exact condition of the target vessels and material before and after each Test so that the nature and extent of damage caused by each Test could be established fully and clearly.

7.002 Determining Damage to Target Vessels.

A. Introduction. The plans for determining damage to target vessels were necessarily based on theoretical predictions rather than on experience, since never before had vessels been damaged by explosions so general and violent as atomic bomb explosions. No vessel -- with the possible exception of submarines -- had ever been subjected to very high pressures exerted uniformly on sides and bottom throughout the entire ship's length. (Of course, mining attacks had provided some experience with high pressures over fairly large portions of the bottoms and sides of surface vessels, and groundings had produced high (localized) pressures on ship bottoms.)

To fill partially the gaps in our ability to predict the pressure effects of an atomic bomb, the Navy conducted model tests during the winter of 1945-46. First plans, made by BuOrd and calling for use of large explosive charges, had to be abandoned for lack of time. Instead, small-scale tests were conducted by the David Taylor Model Basin. These tests, made during the early part of 1946 using small explosive charges, detonated close to idealized models of Victory ships provided data which turned out to be very useful in predicting actual A-Day and B-Day results. (See a later chapter.)

B. Terms for Expressing Damage. The Director of Ship Material described damage in (1) functional-disability terms (e.g., reductions in speed and fire power, or need for ship to be drydocked), (2) geometric and mechanical engineering terms (e.g., ruptures and distortions), and (3) repair-time terms.

C. Readying the Target Vessels. The large if not spectacular job of readying the target vessels for the Tests was carried out principally by the U. S. Naval Shipyards at Philadelphia, Terminal Island, San Francisco, Mare Island, Bremerton, and Pearl Harbor, and by the officers and crews of the target vessels themselves.

Readying the target vessels included the seven activities described below:

1. Conditioning. To the extent that time permitted, target vessels were placed in the best possible condition of structural strength and watertightness. Serious defects in vital machinery and equipment were corrected. Lists were eliminated by transferring oil or water ballast.

2. Loading. Loadings of the target vessels were arranged so as to bring them approximately to their normal battle or operating displacements. Varying percentages of normal loadings of fuel oil, lubricating oil, and gasoline were used. (For a detailed discussion of policy on fuel and ammunition loadings see Chap. 6.)

3. Instrumentation. Special instruments required by the various scientific groups were installed in the target vessels.

4. Preparing Operating Equipment. Although the great majority of the machinery and equipment installed in the target vessels had to be shut down at the time of the Tests because of the absence of crews, certain items of electronic and ordnance equipment were energized and operating at the time the bombs exploded. In general, before each test, auxiliary machinery as well as main propulsion machinery were secured. Valves, of course, were closed in accordance with usual practice -- to prevent flooding of adjacent compartments in case of rupture.

5. Removing Equipment. Much equipment, valuable for historical or other purpose, was removed from the target vessels.

6. Loading Special Test Materials. Special Army and Navy materials not normally carried aboard ships were placed aboard for

exposure to the atomic bomb explosions.

7. Mooring and Anchoring. This was done under the direction and control of Rear Adm. F. G. Fahrion, Commander of Task Group 1.2. The target vessels near the center of the array were moored bow and stern to buoys and thence to concrete blocks attached to anchors; the outer vessels were secured adequately, although less elaborately.

A number of submarines were secured approximately midway between the lagoon surface and the lagoon bottom. To submerge a submarine, a 20-ton weight was hung by a chain of suitable length from the bow, and the stern was similarly weighted. Ballast was then taken into the submarine until she submerged to such an extent that the weights rested on the bottom.

D. Inspection of Target Vessels.

1. Introduction. From surveying the various methods of inspection used by the Board of Inspection and Survey, Forces Afloat, and other inspection agencies, it became apparent that previous methods of inspection were not adequate for the problem in hand. Preparation of extensive new sets of instructions, specifying in detail the necessary procedures and providing handy spaces for recording the data, was undertaken immediately. The new instructions, entitled "Instructions for Target Vessels for Tests and Observations by Ship's Force," were issued in Annex X of the Operation Plan. They covered ordnance inspection, ship inspection, and submarine inspection, and insured obtaining complete information on the condition of the ships, their equipment and machinery, before and after each Test.

Preparations were made to insure clear-cut differentiation between primary damage due to the atomic bomb explosion and damage attributed to secondary effects such as fire and ammunition explosions. (This proved to be very difficult in some cases.)

Extensive use was made of photography as a means of permanently recording the "before and after" conditions of the ships and material. Other data were obtained from visual examination, laboratory study of selected specimens, tests on actual operating performance of machinery and equipment, and readings from special instruments.

2. Inspection Categories. The ship inspection program included the following categories: Hull, Stability, Machinery, Electrical and Electronics Equipment.

(a) Hull Inspection. Hull inspections included (1) tanks, cofferdams, and voids (2) exterior and (3) compartments. After inspecting damage to tanks, for example, the inspectors recorded on specially prepared forms the tank capacities, sounding data, and the nature of the tank interiors (whether dry, filled with salt water, oil, gasoline, etc.). The results of a structural examination of the hull were recorded also (i.e., intact, missing, demolished, or damaged). Also noted was distortion of shapes and surfaces (dished, bulged, or otherwise distorted), openings in surfaces (ruptured, cracked, or punctured), and joint failures. Hull exteriors were examined in much the same manner as the interiors; distortions, openings, and joint failures were recorded on suitable forms. The hull exterior inspections included (1) structure, foundations, and armor, (2) stowage and access closures, and (3) rigging, paint, and coverings. Compartments were inspected in a generally similar manner.

In order to measure hog, sag, twist, bend, and deflections of bulkheads, decks, and deck houses, a number of basic reference planes were established on each ship. These planes were fixed by surveying instruments, plumb bobs, twist pendulums, water-level readings. In addition, pipe deflection gages and scratch gages were installed in various locations to indicate maximum movements of decks, bulkheads, and other ship structures.

For determining changes in watertightness of target vessels it was found desirable to air-test the compartments of each target vessel before and after each atomic bomb test. All the compartments of destroyers were thus tested, but shortage of time permitted testing only selected groups of compartments on large combatant ships (compartments in the bow and stern, at the forward and after quarter points, and amidships).

The results of the watertightness surveys made before Test A indicated that well over half of the main compartments of most of the major ships were classed as "Unsatisfactory" under standards established before the war. Approximately 50 percent of all the leaks consisted of small holes or loose-stuffing tubes, as for electric cables. Most of these leaks could be stopped or greatly reduced if damage control parties were aboard. Of course, in single-skin ships such as destroyers which may spring large leaks through the outer shell into all compartments simultaneously, precautions against intercompartment flooding may be of little avail; but in the larger ships, which are well protected throughout the middle regions but are vulnerable at the ends, good compartmentation and damage control may prevent end flooding from spreading along the ship and sinking her.

(b) Stability Inspection. To determine the ability of various types of naval vessels to remain afloat and upright despite flooding caused by an atomic bomb explosion, plans were made for obtaining accurate information on the stability and loading of each target vessel before and after each Test.

Stability was determined from observations of period of roll. The period of roll was first determined at sea prior to arrival in the target area. Sallying experiments were also carried out on certain vessels in the target area before they were evacuated prior to each Test. (In a sallying experiment, a vessel is given an artificially induced roll by having men run from one side to the other--on signal--until the vessel rolls several degrees.) The metacentric height was calculated from the period-of-roll data.

Forward and after drafts were also reported for each target vessel. Series of horizontal white lines, painted (on the sides of the vessels) just above the waterline made it relatively easy, even from an observation airplane, to determine draft.

For each target vessel reports were made as to the weights and centers-of-gravity of loads (other than liquid loads) on board just prior to each Test. Other reports were made on liquid loadings, covering the loadings of each tank, void, and cofferdam before and after each Test. Loadings were determined by soundings. By comparing soundings made before and after each Test, and by making the usual computations, the impairment of stability was determined.

(c) Machinery Inspection. This inspection provided a description of damage to each target vessel's machinery, including such items as the main propulsion plant, boilers, boiler foundations, electrical power plants, blowers, shafting and bearings, pumps, refrigeration equipment, and steering gear. Pre-test defects in machinery were noted in all cases.

The attempt was made to operate all machinery after each Test unless it was obviously inoperable.

(d) Electrical Equipment Inspection. This inspection provided a description of damage to representative electrical equipment including generators, switchboards, transformers, submarine main batteries, motors, motor generators, lighting systems, and degaussing equipment.

(e) Electronics Equipment Inspection. This inspection included examination of ship's interior electronic communication equipment and also radios, radiosondes, radars, IFF systems, sonars, radar repeaters, homing devices, and radar beacons.

(f) Ship's Magnetic Field Values. (signatures) Magnetic field values were determined, by means of indicating magnetometers, before and after each Test, for the purpose of seeing whether the explosion produced magnetic changes such as might change the ship's susceptibility to magnetic mines.

7.003 Determining Damage to Target Aircraft.

A. Introduction. The target aircraft exposure plan provided for the exposure of airborne Army and Navy drones as well as the exposure of aircraft and aircraft parts on the decks of target vessels. In general, damage was determined from visual inspection.

B. Naval Aircraft.

1. Naval Drone Planes. A function of the Naval drone planes was to serve as airborne target aircraft, although their primary function was to collect air samples. Plans for thus determining damage to airborne aircraft involved the use of four Navy F6F radio-controlled drones flying, each at a different altitude, through the Test-A radioactive cloud approximately 8 min after the detonation; altitudes chosen were: 10,000, 16,000, 20,000, and 28,000 ft. Each drone was equipped with VGTA instruments which recorded velocity, acceleration, and altitude as functions of time. They were to be landed at Roi for inspection for damage and radioactivity. (Actually, only three drone planes flew through the radioactive cloud, because one crashed prior to Mike Hour.)

For Test B a similar plan was followed, 4 drones being used, flying over the point of detonation approximately 3 to 4 sec after the explosion.

2. Naval Aircraft Aboard Ships. The plan for exposure of Naval planes aboard target ships closely paralleled the target ship exposure plan. A total of 71 target aircraft were placed on the decks of 22 different target ships. In addition, 2 seaplanes were moored in the target area.

To insure obtaining complete information on the strength of all aircraft components, the aircraft were placed in combat-ready condition, i.e., fully equipped insofar as availability of surplus material permitted.

Two planes, a VSB and a VTB, with fuel and lubricating oil tanks full, were placed at the extreme after end of the flight deck of the SARATOGA. Steel drain pans were fitted under them so that in the event of a gasoline leak the gasoline would drain overboard. In addition, one VSB and one VTB each with full load of gasoline and lubricating oil were placed at the extreme after end of the flight deck of the INDEPENDENCE. Steel drain pans similar to those used on the SARATOGA were placed under them.

All other aircraft exposed were completely drained of gasoline and lubricating oil.

In general all bombs, rockets, torpedoes, and flares were removed from the planes. However, weapons such as inert-loaded bombs, torpedoes, or rockets, were placed on some of the planes.

Guns were rendered inoperable by removal of bolts. Ammunition was limited to 10 rounds per gun; first rounds were secured in their receivers.

Cables were used to secure the aircraft against heavy weather. Extra cables were provided for some aircraft in more exposed positions to prevent loss or dislocation from the blast. The seaplanes were moored very securely.

Accelerometers and V6-Recorders were installed in a small number of target aircraft to record the accelerations encountered during Test A. Empty, sealed, 5-gallon cans also were placed in the cockpits of a number of these aircraft. This type of instrument was roughly representative of the size and shape of a man's chest, and its condition after Test A was an indication of what might have happened to a pilot in the airplane with respect to crushing of the chest.

The target aircraft inspections covered: Aircraft Power Plants, Aircraft Armaments, Aircraft Electronics Equipment, Aircraft Structures, Aircraft Miscellaneous Equipment and Ships' Installations for Handling Aircraft such as Catapult, Arresting Gear, Airplane Cranes, and Elevators.

<u>C. Army Aircraft and Aircraft Parts.</u>

<u>1. Army Drone Planes.</u> One B-17 drone plane flew through the Test-A radioactive cloud approximately 7.5 min after the detonation, and three B-17 drone planes flew around the radioactive cloud. Each drone flew at a different altitude; altitudes chosen were: 13,000, 18,000, 24,000, and 30,000 ft. In Test B, 4 B-17 drones were flown directly over the Zeropoint. Drones Nos. 1 and 3 flew at 6,000 ft and 16,000 ft, respectively, arriving over the Zeropoint at the instant of detonation. Drone No. 2 flew at 7,000 ft, arriving over the Zeropoint 5 min after the detonation. Drone No. 4 flew at 11,000 ft, arriving over the Zeropoint 8 min after the detonation.

All of the Army drones carried Hathaway flight analyzers which recorded normal accelerations, air speeds, and pressures. Indicating accelerometers were also used in a television-telemetering arrangement.

The drones were landed at Eniwetok and examined for radioactivity and damage.

2. Army Aircraft Parts Aboard Ship. A number of Army aircraft parts were placed on the decks of target ships. Several types of wing panels constructed of wood, magnesium, various bonded metals, and magnesium alloy were secured to the decks.

In addition, wing tanks, stabilizer sections, 7 types of fire extinguishers, a P-47 fuselage, and an altimeter were exposed. These items were inspected after the Tests in accordance with standard procedures.

7.004 Determining Damage to Material.

A. Introduction. Besides vessels and aircraft, large quantities of material of many types were exposed to the atomic bomb explosions. For these also it was important to obtain graded damage and to learn how to increase their resistance to atomic bombing. In addition to the Naval material normally aboard vessels, much Army material was exposed on the decks of the target vessels. The requirement for exposing Army material stemmed from the Joint Chiefs of Staff directive that--consistent with attainment of the primary objective of determining the effects of atomic bombs on vessels--all possible information be obtained as to the effects on military material of all types (including installations and facilities on shore).

In view of the very gradual falling off from the shore of the bottom of the lagoon--requiring locating the target fleet a considerable distance offshore--it was not feasible, in most cases, to locate target material on land. Consequently, the majority of the material was exposed on the decks of the target vessels although some was exposed on shore and on beached vessels. In general, the Army and Navy material exposed embraced ordnance and quartermaster material. In addition, the Army material included signal, engineer, and chemical warfare equipment. As in the case of the target vessels, all of the material was inspected before and after each Test to determine the extent of damage.

B. Ordnance Material.

1. Naval Ordnance Material. The Naval ordnance material exposed embraced five categories: Fire Control Equipment; Guns, Mounts, Turrets and Armor; Explosives; Aviation Ordnance; Underwater Ordnance.

(a) Naval Fire Control Equipment. Included in this category was gun battery alignment; optical equipment including binoculars, gunsights, rangefinders, telescopes and periscopes; surface fire control equipment including directors and computers; torpedo course indicators and directors; submarine fire control equipment including bearing and range indicators, gyro setting indicators, target bearing transmitters, torpedo data computers; and fire control radar.

Gun battery alignment checks were made on all target vessels before and after each Test to measure and record any misalignment caused by the explosions. Selected gun fire control systems and gun directors were prepared for actual operation during Test A.

(b) Naval Guns, Mounts, Turrets, Armor. Many items of standard Naval ordnance equipment, including guns, mounts, turrets, armor, were exposed in their normal positions as parts of the target vessels. Other material exposed included machine guns, gun mounts, gun parts, and rocket launchers. Special armor plates and metallurgical samples of known chemical and physical properties representing the various types of current manufacture were secured to the decks of selected target ships. After each Test, some of the plates and samples were returned to the Armor and Projectile Laboratory, Naval Proving Grounds, Dahlgren, Virginia, for metallurgical and ballistic examination.

Other material exposed included: close-range weapons; turrets and mounts; guns, mechanisms, housings; gun batteries; and rocket launchers.

(c) Naval Ammunition and Explosives. In addition to various percentages of wartime service ammunition allowance, special test ammunition and explosives (including bombs and bomb fuzes, rockets and rocket fuzes) were exposed on the target vessels.

During the early periods of planning the JTF-1 Operation and through the middle of March 1946, frequent changes in the target array somewhat handicapped the planning of the placement of explosives aboard target vessels. One of the major changes which had not been anticipated at the outset was the decision early in March 1946 to place large percentages of service ammunition, fuel oil, and gasoline in most of the target vessels. The original plan of the Ordnance Material Equipment Committee, which had charge of the ordnance equipment exposure, had been to place small (token) quantities of special ammunition on vessels at various distances from the Zeropoint. Despite the decision calling for large quantities of service ammunition to be placed on most of the target vessels, it was decided to place the special ammunition on as many vessels as possible in order to obtain the maximum amount of information.

(d) Aviation Ordnance. Included in the aviation ordnance inspection were bombs, bomb directors, bombsights, gunsights, machine gun ammunition, aircraft machine guns and rockets.

(e) Naval Underwater Ordnance. Underwater ordnance material exposed included mines, depth charges and projectors, torpedoes, and torpedo tubes.

The mines were in standard condition for transporting prior to laying except that the main charges were replaced by inert material. Since the detonators and boosters were installed in a normal manner, damage to firing mechanisms would be indicated by exploded booster charges and detonators.

Torpedoes and depth charges were prepared in two ways: (a) normal condition without booster and detonator but with main charge and (b) normal condition with booster and detonator installed and inert material to replace the main charge. Thus a sensitive explosive would not necessarily detonate a less sensitive charge.

Among the early proposals by the BuOrd Research and Development Division was the proposal to lay fields of inert mines in the Bikini harbor area at various distances from the intended Zero-point in order to determine the effect of the explosions on the firing mechanisms. After some discussion the proposal was rejected by Admiral Blandy in late February 1946, due to the crowded conditions in the harbor.

2. Army Ordnance Material. The Army Ordnance material exposed included materiel and ammunition. Forty-five materiel items were placed on the decks of 4 target battleships and included small arms, light and heavy artillery, fire control directors, range finders, rocket launchers, tanks, and armored cars. In addition, 99 ammunition items were exposed on 4 LST's and 1 oil barge. These items were arranged in sets and included cartridges, shells, fuzes, rockets, flares, bombs, dynamite charges, grenades, mines, and Bangalore torpedoes.

C. Provisions and Clothing. It was recognized that, independent of the damage to ship structures, severe damage to provisions and clothing could impair the fighting efficiency of a ship. Effects of exposure on Army provisions, clothing, etc., were of interest also.

Sample kits of provisions, clothing, etc., were placed aboard NEVADA, ARKANSAS, CARTERET, and SARATOGA. In most instances these items were stored in the ships' regular stowage spaces. Swatches of various cloths were mounted on plywood boards which were exposed topside on a number of ships throughout the target array. The amount of flash exposure of each sample was determined roughly by the extent of discoloration of the plywood.

Test lots of over 150 standard articles of Army food and clothing were exposed on the weather decks of 11 target ships. Also, field equipment and samples of aeronautical fuels and lubricants were exposed. Five types of fuels and lubricants were used, one sample of each type being placed on the concrete drydock (ARDC-B), and similarly for each of the 4 LCT's located down-wind in the target array at such distances as to minimize the possibility that harmful fires might break out. The beneficial effects of shielding a variety of material from radioactivity were investigated using various kinds of shielding materials, such as lead and wax.

D. Engineer Material. The engineer material, exposed on 3 APA's, included such items as infrared equipment, landing mats, and water distillation equipment.

E. Chemical Warfare Material. The chemical warfare material exposed included such items as bombs and shells containing simulated chemical warfare fillings and also included decontamination agents, protective clothing, and gas masks.

F. Signal Material. The signal material prepared for the Tests was divided into two classes. First, material exposed on the decks of target vessels to determine physical damage; and second, radio and radar equipment set up in full running condition aboard the ships and on the islands to determine the effect of radioactivity on the performance of the equipment. Representative items of field and communication equipment were exposed, including telephones, teletypewriters, sound-locating sets, and radio and radar gear.

G. Medical Material. Much medical equipment was exposed, including vaccines, viruses, toxins, antiserums, bacteriophages, hormones, vitamins, and dental supplies.

Investigations were made of the effectiveness of air filtering equipment, protective creams, and protective clothing.

Chapter 8

Technical Preparations for Determining Injury to Animals and Plants

Outline

Chapter 8

Technical Preparations for Determining Injury to Animals and Plants

8.001 Introduction.

The medical groups investigating injuries to Nagasaki inhabitants found that, besides the persons killed instantly by the atomic bombs, many persons -- including even persons located more than a mile from the explosion -- suffered serious injuries of several types. First, second, and third degree burns of skin were very common. Many persons developed a disease, now known as radiation sickness which was apparently independent of mechanical or thermal injuries and was often fatal; it was presumably caused by intense gamma radiation.

Because most of the casualties were not given adequate medical care and were not examined carefully until several weeks after the explosion, the biological and medical information obtained was not wholly adequate. And, of course, it was impossible to make any accurate correlation between injury and pressure, radiation, etc.

Consequently, a major effort was made in Operation Crossroads to obtain data on injury to animals. By correlating the injury data with the pressure and radiation data, and by interpreting the data in terms of damage to men, means presumably could be devised for reducing injury to personnel subjected to atomic bombing, for diagnosing such injury promptly, and for mitigating the effects.

The number of animals used was kept to the minimum compatible with obtaining information which would be effective in showing how injury to personnel could be prevented or reduced in atomic bomb warfare. The decision to use animals was adopted only after all available means, for measuring mechanically the anticipated physical and biological effects, had been investigated and had proved inadequate. Use of dogs was foregone in deference to the pleas of a section of the public.

8.002 Mammals.

The following mammals were exposed:

	Test A	Test B
Pigs	147	20
Goats	176	0
Rats	3030	200
Mice	109	0
Guinea Pigs	57	0

All these types of mammals endure tropical climates and can survive for a relatively long time without attention (except guinea pigs).

Pigs were chosen because their skin and short hair are comparable to man's; goats were chosen because their weight is comparable to man's and the quantity of their body fluids is sufficient for extensive laboratory analysis (four of the goats were selected for their psychoneurotic tendencies); rats were chosen because the responses of their tissues and blood to radiation are known and have been correlated with the corresponding responses in man; mice were chosen from special strains, some with high and some with low predilection to cancer.

Also, it was desirable to select mammals having approximately the same resistance as humans to nuclear radiations, e.g., goats and pigs, and animals having considerably more resistance, e.g., rats, and other animals having less resistance, e.g., guinea pigs.

The animals were transported in the BURLESON (APA-67), which departed San Francisco 1 June 46, making a late and direct trip so that the animals would be in the best possible condition on A-Day.

Some of the animals were kept on BURLESON as "controls"; but the majority were placed on these target vessels: NEVADA, SAKAWA, INDEPENDENCE, SALT LAKE CITY, PENNSYLVANIA, PARCHE SS 384, and 16 other vessels (principally APA's and DD's). These vessels represented a wide range of distances from the Zeropoint; the desire was, of course, to produce injury having a wide range of severity. Some animals were tethered; others were free to roam within cages or compartments. Some were placed above decks, others below. Since the vessels were to have little or no ventilation for several days, the choice of suitable compartments was limited.

A number of the animals were specially prepared. Some goats were clipped to hair-length similar to man's; some goats were partially covered by special protective clothing or by antiflash creams. Blood counts were made of most animals before the explosion as bases for comparison with post-explosion counts. Some animals were supplied with filtered air and were thus kept from being exposed to particulate fission products.

To make it possible to correlate injury with pressure, radiation, etc., an elaborate instrumentation scheme was worked out. Near each group of animals one or more sets of instruments were set up to measure intensity and duration of heating effects, air pressure, wind velocity, surface acceleration, and optical, gamma-ray, and neutron radiations. The more specialized test instruments used included:

- 4 Sonne cameras (for recording on film the intensity of gamma-ray radiation as a function of time)
- Several R Meters (simple ionization chambers)
- 100 air-pressure gages
- 10 Geiger counters (for safety monitoring, for evaluating radioactivity in biological material, etc.)
- 2000 photographic gamma-ray recorders
- Several ultraviolet recorders
- Several temperature recorders

Much standard medical laboratory equipment was used also. Injury was evaluated by examining the animals, noting their location and degree of protection, and obtaining statistics on deaths, survivals, and various types and degrees of injury. At varying intervals following exposure, pigs, goats, and rats were killed and examined in order that physical effects as a function of time might be accurately determined. Injury data were correlated with pressure and radiation data, and estimates were made as to the injuries which would have been suffered by personnel. The estimates were based, of course, on known relationships between the effects of shock, high temperature, and ionizing radiation upon test animals and the effects of similar influences upon men.

8.003 Bacteria.

Bacteria were exposed in metal-enclosed, sealed glass containers. It was thought that mutations or other changes of military or medical interest might be produced.

8.004 Insects and Flies.

Exposure of grain insects was arranged also, in order to test the genetic effects of radiation on the germ cells of the insects themselves and on their progeny throughout several succeeding generations.

8.005 Fish and Other Marine Life.

Extensive studies were made on the effects of the detonation on fish to determine whether, in wartime, a country's resources of fish could be destroyed to any appreciable extent; also to obtain data which could be used to inform the fishing industry as to the extent to which their resources of fish actually were destroyed in the Tests. Of particular interest were the questions: What percentages of the Lagoon fish populations would be destroyed immediately? What percentages of fish would die later from exposure to radioactivity? How rapidly would the population deficiencies be corrected by immigration and reproduction?

The studies included "strip censuses", taken before and after the explosions, and also "control" censuses made at another (unaffected) atoll, namely Rongerik, which is 125 mi east of Bikini.

Sonar (acoustical) devices were used in locating schools of fish.

New techniques of poisoning reef fishes were developed which greatly facilitated the work of taking censuses in the neighborhood of reefs. Rotenone was found to be a remarkably effective poison.

Over 20,000 fish were caught by hook, net, and seine. Many were caught at night, being attracted by artificial lights.

Unfortunately, 98 percent of the pelagic fish specimens were lost when YP636 went aground 30 mi south of San Francisco on 13 Sept 46. Salvage efforts resulted in saving only 2 percent.

Other marine animal life was studied also, including, for example, coral and barnacles.

8.006 Plants.

Packets of seeds were exposed. Some mutations were expected.

Other plant life was studied also, including algae.

Chapter 9

Other Technical Preparations

Outline

Section

Chapter 9

Other Technical Preparations

9.001 Introduction.

The obtaining of extensive pressure, radiation, etc., data was vital to any adequate correlation between damage and cause of damage. These data were required also in making any extrapolations of Crossroads damage results to situations involving vessels of other types— present or future — and to atomic bombs of different power and different altitude of detonation. The data were needed also in determining the amount of energy released by the bomb. They were essential also to any adequate correlation between injury to animals (or crews) and cause of injury. Finally, these data were of scientific interest in their own right.

The following discussion of technical preparations is arranged according to instrument function and is very brief. Full accounts of the principal instruments used are contained in Annex G (Revised) to the Operation Plan.

9.002 Preparations for Determining the Development of the Fireball.

A. Goggles. Since, on A-Day, the maximum amount of visible light emitted from unit area of the detonation region proper would be several times greater than from unit area of the sun, it was expected that anyone attempting to view the explosion with his naked eye would be momentarily (although probably not permanently) blinded. It was thought that the infrared light also would constitute a hazard to eyes. Consequently 6000 pairs of dark goggles of density 4.5 were obtained for use by key personnel. (Actually these goggles were unnecessarily dense.) Other persons were advised to cover their eyes with a forearm and to face away from the Zeropoint. (Almost no visible radiation was expected on B-Day, and no special precautions were prescribed.)

B. Icaroscope. A few persons viewed the A-Day explosion through Icaroscopes, devices developed for viewing enemy airplanes approaching "out of the sun." The Icaroscope is an "optical radiation intensity limiter" by means of which the observer's eye receives not direct light from the objects viewed but receives light from an image produced by a phosphorescent screen. The Icaroscope uses a fine grain phosphor and affords angular resolution of approximately [redacted] one minute. Approximately 50 Icaroscopes were used; several were fitted with motion-picture cameras.

C. Bowen Camera. Bowen camera, a highly specialized type of camera intended to record the general appearance of the A-Day detonation proper and the development of the fireball, was rendered ineffective by the A-Day timing signal failure. (This camera contained 76 lenses and a vernier-shutter; it was intended to take pictures each with exposure time of one microsecond, and was intended to operate for only 220 microseconds.)

D. O'Brien Camera. The O'Brien camera afforded even higher time resolution i.e., 0.1 microseconds, in photographing the A-Day detonation. Its strip film was mounted on the inside of a rapidly-rotating drum. Its angular resolution correspohded to 3 ft of arc at 7 mi. One O'Brien camera, mounted on BARTON obtained valuable data on the development of the fireball; the other O'Brien camera, located on Bikini Atoll, was rendered ineffective by the A-Day timing signal failure.

E. Other Cameras. Of course, an enormous number of cameras of conventional and semi-conventional types were used for recording the explosion as a whole and the damage produced. (See Sec. 3.020.) Eastman high-speed cameras and Fastax cameras were among the most important.

9.003 Preparations for Determining Peak Pressure in Air.

Preparations for determining peak pressure in air involved procuring, testing, and installing gages of the types described below. Many of the gages were designed and constructed especially for these (or previous) atomic bomb tests. The majority of the gages were intended to operate in the so-called "Mach Stem" region. (This is the air region in which the direct pressure wave and the pressure wave reflected from the surface of the water are so close together as to coalesce to form a single wave. The combined wave has roughly the form of a cylinder, whose axis is the vertical line through the Zero-point. The Mach Stem region is particularly important since the intensity of the pressure wave is abnormally great there.) Some of the gages were placed in exposed positions; others were placed in turrets or other interior spaces of the target vessels.

Some of the gages were attached to floats in order that they could be recovered readily even if the target vessels on which they had been placed were to sink.

Practically all gages were of recording type and were relatively unaffected by exposure to heat, moisture, or salt. (Initially some trouble was encountered from corrosion in gages employing aluminum foil.)

A. Ball-Crusher Peak-Pressure Gage. This gage was used to measure peak pressure in the range 50 to 10,000 psi. It consisted essentially of a hollow cylinder 3 in. long and 1½ in. in diameter, a solid piston, a soft copper ball of 3/8 or 5/32-in. diameter. The pressure wave drove the piston against the ball, partially flattening it. A microscope was used to measure the flattening, the extent of which was simply related to the peak pressure.

B. Ruptured Foil Peak-Pressure Gage. This gage was used to measure peak pressure in the range from 0 to 50 psi. It consisted of a sheet of aluminum foil clamped between 1/4-in. brass plates each pierced by a graduated series of holes of diameters up to 2 in. The gradation in diameter from one hole to the next was such that the increments of pressure corresponding to rupture of the foil at successive apertures were in geometrical series. The assembly was protected at the rear by a sturdy air-tight cover, to prevent instantaneous equalization of pressure. These gages were mounted typically in groups of 5 on an open steel framework approximately 7 ft high, placed on exposed decks. Many of the gages were placed inside turrets and other interior spaces of the target vessels.

C. Deformed Plate Peak-Pressure Gage. This gage was used to determine peak pressure in the range from 60 to 1000 psi or 20 to 2000 psi. It consisted of an aluminum or copper plate, supported at the edges and protected at the rear, which was deformed (or, in cases of very high pressure, ruptured) by the pressure wave. Peak pressure was computed from the extent of deformation.

D. Can Type Peak-Pressure Gage. This gage was used to determine peak pressure in the range from 5 to 150 psi. It consisted of a simple, thin-walled, closed can or drum which was partially crushed by the pressure wave in air. Peak pressure was computed from the extent of crushing.

E. Pipe Type Peak-Pressure Gage. This gage was used to measure peak pressure of the order of 1000 psi. It consisted of a graded series ("harp") of pipes. Peak pressure was computed on the basis of observations as to which pipes were bent and how much they were bent.

F. Indentation Peak-Pressure Gage. This gage was used to measure peak pressure in the range from 20 to 1000 psi or 100 to 6000 psi. Pressure was recorded in terms of the indentation produced by a steel ball in a block of lead, the ball and block being contained between two flexible steel diaphragms.

G. Aneroid Barometer Type Peak-Pressure Gage. This gage records peak pressure data on a blackened disk. It was designed for use inside target vessels.

H. Liquid Trap Type Peak-Pressure Gage. This gage records pressure in terms of the amount of liquid displaced by the pressure wave and trapped. It was designed for use inside target vessels.

9.004 Preparations for Determining Air Pressure versus Time.

Although more difficult to obtain than peak-pressure data, air pressure-versus-time data were particularly valuable. They made it possible to determine impulse; they served to corroborate the peak-pressure data, and they provided information as to the character of the shock wave.

The principal air pressure-versus-time gages are described below:

A. Mechanical Pressure-versus-Time Gage. High-Frequency Type. This gage was used to record air pressure as a function of time linearly in the range 20 to 200 psi, or 100 to 1000 psi and logarithmically in the range 80 to 800 psi or 120 to 1200 psi or 40 to 4000 psi. In a typical recorder a moving stylus etched or scratched its record on a rotating disk or cylinder, which made one revolution and then stopped. The diaphragm displaced by the pressure wave moved against an opposing spring operating within its elastic limit, so that the full course of the rise and fall of pressure was recorded with reasonable faithfulness.

B. Mechanical Pressure-versus-Time Gage. Low-Frequency Type. This (DeJuhasz type) gage was of engine-indicator type; low-frequency pressure values in the range from 0 to 2000 psi were determined mechanically and were recorded by a stylus on a roll of waxed paper.

C. Strained-Wire Pressure-versus-Time Gage. These gages, some of Taylor Model Basin type and some of Stratham type, recorded pressure in terms of the change in electrical resistance of a wire strained by the displacement produced by the pressure wave. Data were recorded on Brush oscillograph recorders and Highland String-Oscillographs; in some cases the resistance data were immediately broadcast to recorders located at a distance (telemetered).

D. Condenser-Microphone Radiosonde Pressure-versus-Time Gage. This gage was dropped from high-altitude airplanes at distances of several miles; it thus measured pressure in the free field, outside the Mach Stem region. The gage operated by transmitting (by frequency modulation) a signal whose strength varied with the deflection of a diaphragm serving as one plate of a condenser. A ground station received the signal and photographed the oscilloscope trace resulting.

E. Microbarograph. This gage was used at remote locations to measure the small (very low-frequency) pressure changes produced there.

9.005 Preparations for Determining Velocity of Shock Wave in Air.

Velocity of the shock wave in air in the Mach Stem region was determined by several methods, among the methods readied were those involving the instruments described below:

A. Sonobuoys. Arrangements were made for receiving radio signals (indicative of arrival of shock wave in air) from series of special sonobuoys placed along a radial line and with carefully measured spacing.

B. Cameras. Several Eastman Type III high-speed 16-mm motion-picture cameras, of focal length 17 in., were set up on Amen to photograph the shock wave in air. Of the order of 1000 frames/sec were exposed, and accurate timing signals were superimposed on the film. Photographs revealed the shock wave in mid-air and also the circle of intersection of the shock wave with the Lagoon surface.

C. Argon Flash Units. Arrangements were made for photographing argon flash lamps located on target vessels and triggered by the shock wave in air. Photography was by 35-mm General Radio continuous-motion streak cameras located in Tower C on Amen. Accurate timing signals were superimposed on the film.

D. Magnetic Recording Blast Switches. Arrangements were made for recording on high-speed magnetic tapes the times of triggering of blast-operated switches arranged in pairs.

E. Interrupted Light Beam Recorder. Arrangements were made for photographically recording the time interval between interruptions (produced by passage of the shock wave in air) in steady beams of light passing from a position very near the camera to dihedral mirrors on target vessels and thence back to the camera.

Of course, shock-wave velocity can be computed from pressure data. The equation applicable to the region in which the pressure was less than 500 psi is:

$$P = \frac{7}{6} P_o \left[\left(\frac{U}{a} \right)^2 - 1 \right] \quad \text{(Eq. 1)}$$

Where U is the shock-wave velocity in ft/sec, P is the shock-wave pressure in psi, P_o is the ambient atmospheric pressure, and a is the ambient velocity of sound in ft/sec. (Ref. 300-13)

9.006 Preparations for Determining Impulse in Air.

Impulse, being simply the time integral of pressure, is readily computable from the pressure-versus-time data, measurement of which has been discussed in a previous section. At moderate and great distances from the Zeropoint (i.e., at points where the peak pressure is less than 500 psi), the net impulse is, of course, zero.

Close to the Zeropoint the impulse value may approach: 0.367 P_oT_o where P_o is the peak pressure (psi) at the point under consideration, T_o is the duration (sec) of the positive pressure pulse at that point.

Preparations were made for obtaining relatively direct data on impulse by means of 35 free piston impulse recorders located on target vessels. The timing signal failure on A-Day prevented obtaining the valuable results expected.

9.007 Preparations for Determining Pressure etc., in Water.

Extensive preparations were made for determining pressure in water, particularly in Test B.

A. Peak Pressure. Peak pressure in water was determined by gages of the following types:

1. Ball-Crusher Peak-Pressure Gage. These gages were similar to those described in Sec. 9.003, and were located at a great variety of ranges and depths. Locations were chosen to provide data on reflection of the pressure wave by ships' hulls and on attenuation of pressure close to the surface of the water.

2. Indentation Peak-Pressure Gage. These gages were similar in operating principle to those described in Sec. 9.003.

3. Ruptured Foil Peak-Pressure Gage. These gages were

similar in operating principle to those described in Sec. 9.003.

4. Deformed Plate Peak-Pressure Gage. This gage measured peak pressure in terms of permanent deformation produced in aluminum or copper diaphragms. Pressures up to 6000 psi could be measured.

B. Pressure-versus-Time. Underwater pressure-versus-time was measured by gages of the following types:

1. Piezoelectric Pressure-versus-Time Gage. This gage recorded pressure as a function of time in terms of the compression of a piezoelectric tourmaline crystal.

2. Mechanical Pressure-versus-Time Gage, High-Frequency Type. This gage was similar in principle to that described in Sec. 9.004.

3. Mechanical Pressure-versus-Time Gage, Hilliar Type. This gage contains a graded series of freely-moving steel pistons of different mass, which strike and deform small copper cylinders; analysis of the variations in the deformations of the cylinders provides the desired pressure-versus-time data.

C. Impulse. Impulse transmitted through the water was measured indirectly by the pressure-versus-time gages described above and by the following:

1. Deformed Diaphragm Impulse Gage, British Type. This gage operates on the same principle used in the diaphragm gages discussed above.

2. Deformed Diaphragm Impulse Gage, UERL Type. This gage also is generally similar in operating principle to diaphragm gages discussed above.

3. Deformed Cylinder Impulse Gage. This gage contains a single freely-moving cylinder which produces a deformation in a copper cylinder. The extent of deformation is indicative of the maximum momentum of the piston.

D. Low-Frequency Sound. Measurements were made of low-frequency sound in water in order to find whether atomic bomb explosions might set off acoustical mines. Measurements were made by hydrophones moored near the bottom of the Lagoon; the recorders, of pen-and-ink or magnetic recording type, were situated on Enyu Island.

9.008 Preparations for Measuring Optical Radiation.

A. Time-Integrated Energy of Optical Radiation. Time-integrated energy of optical radiation emitted in the explosion was measured by unfocused thermocouples provided with pen-and-ink type recorders. Various band-pass filters were used in some instances in order to determine the intensity in spectral bands of particular interest.

B. Radiant Energy Emitted by Selected Areas of Fireball and Cloud. Focussed bolometers were used to determine the optical radiation from selected areas of the fireball and cloud.

C. Time Distribution of Optical Radiation. To determine the time distribution of the optical radiation emitted by the explosion use was made of photocells. Photocell transient current was amplified and fed to an oscilloscope whose screen was photographed. Enough units were provided to analyze the phenomena in either of two spectral bands (0.35 to 0.4 microns and 0.8 to 1.0 microns) and in either of two time intervals (100-microsecond interval and 5000-microsecond interval).

D. Spectral Distribution of Optical Radiation. Preparations were made for measuring the spectral distribution of the optical radiation by small spectrographs employing quartz prisms. In addition, rotating-drum spectrographs were prepared, to show the spectral distribution and the time distribution as well. An unfocussed spectrograph of grating type was employed also. A number of band-pass photometers were used to determine the intensity of radiation in bands of especial interest. Plans were made for obtaining additional information as to time distribution by using a photographic method in which a film is moved at high speed past a slit provided with a calibrated neutral filter.

9.009 Preparations for Measuring Nuclear Radiations and Radioactivity.

A. Introduction. Measurement of nuclear radiations and radioactivity essential to determining (1) the amount of energy released by the bomb, (2) when it was safe to re-enter the Lagoon and the target vessels, (3) the decay constant of the radioactivity, (4) what dosages were responsible for the animal symptoms produced, (5) whether personnel received excessive dosages, (6) the relative merits of various methods of decontamination, and (7) the remote detectability of atomic bomb explosions. For these various purposes, many different types of instruments were needed.

B. Neutron Radiation. Time-integrated intensity of neutron radiation was measured by means of sulfur samples, in which neutron capture led, by the (neutron-proton) reaction, to the production of phosphorus. The resulting phosphorus was radioactive, emitting beta particles.

C. Gamma Radiation. Time-integrated intensity of gamma radiation was measured by means of thousands of photographic film badges, each of which contained a small piece of unexposed photographic film. From the film blackening produced by the ambient gamma radiation the time-intensity of the gamma radiation was readily determined.

Instantaneous intensity of gamma radiation was measured by means of the Geiger counter, a device sensitive enough to detect passage of a single quantum of gamma radiation. The majority of the Geiger counters were carried manually and read on the spot; others were of automatic-recording type, or telemetered their findings to persons situated some miles away. Some Geiger counters were mounted in watertight cases and were used beneath the surface of the Lagoon. Others were mounted in drone airplanes. Some were shielded with thick metal slabs so that very high levels of ambient radiation could be measured accurately. Others were shielded merely to show the effectiveness of the shielding materials themselves.

A number of ionization-type gamma-radiation meters were used also. Time distribution of gamma radiation was determined by means of devices containing photographic film moving behind a slit provided with gamma-ray attenuating screens or step wedges of various thicknesses.

D. Other Nuclear Radiations. Little effort was made to measure beta radioactivity. Some alpha radioactivity measurements were made at Kwajalein during the evaluation of the energy release by the radiochemical method described in Chap. 5.

E. Special Sampling Procedures. Proper selection of samples was essential to obtaining reliable conclusions as to radioactivity in the air and in the water. To determine radioactivity in the air, use was made of drone planes carrying Geiger counters and also filters for collecting radioactive particles in the air. To determine radioactivity in the Lagoon samples were taken at a predetermined series of depths and at a predetermined set of plan-view positions. Water samples taken from well beneath the surface of the Lagoon were obtained with the aid of Nansen bottles.

In some instances sampling was continuous, as in continuously pumping water (taken in by a boat underway) past a Geiger counter, or in continuously analyzing the air through which a drone plane is flying.

In some instances the radioactivity was deliberately concentrated and "space-integrated", as with the aid of filters on drone planes.

9.010 Preparations for Determining Ship Response, Other than Damage as Such.

A. Introduction. This Section discusses means of determining mechanical displacement, i.e., translation and distortion, of ships and ship parts; also velocity; acceleration; roll and pitch; only transient, i.e., non-permanent, non-damage, effects are considered. (Means for determining permanent, i.e., damage, effects are discussed in Chap. 7.)

B. Displacement. Several kinds of gages were selected to determine the transient mechanical displacements, i.e., transient translations, transient distortions, produced in ships and ship parts by the explosion. These are discussed separately below;

1. Pallograph Peak Displacement Gage. This device was used to measure vertical and horizontal peak displacement of keels, superstructures, etc. This type of gage employs a seismically (i;e., relatively freely) suspended inertia member whose motion (relative to adjacent rigidly-mounted members) was recorded by scratches on a stationary sheet of wax paper.

2. Bar Type Peak Displacement Gage. This device is similar in function to the Pallograph, but records peak displacement in terms of permanent displacement of a rigidly mounted bar with respect to a freely sliding inertia unit mounted on the bar.

3. Lead Strip Peak Deflection Gage. This device consists essentially of a lead strip which suffers permanent distortion when relative displacement occurs between the two different bodies confining the strip.

4. Rotating-Disk-Recording Displacement Gage. This device is generally similar in function and operating principle to the pallograph peak displacement gage, except that it records displacement as a function of time, and the displacement data are scratched on a rotating disk.

5. Long Base Displacement Gage. This device consists of a long bar (ordinarily, approximately 10 ft long) extending between two parts of a ship. Motion of one part relative to the other causes a telescoping action at one end of the bar, and the extent of travel is indicated by a scriber.

6. Short Base Displacement Gage. This is very similar to the

long base instrument described above, but is shorter.

C. Velocity. Velocity of ship parts was measured principally by a magnetic type velocity gage. This gage consists of a coil mounted relatively freely in a magnetic field. Velocity of the coil with respect to the magnetic field produces in the coil an induced current whose magnitude is recorded on an acetate tape or magnetic tape. Velocities as great as 100 ft/sec may be measured.

D. Acceleration. Acceleration of ship parts was measured by gages of the types described below:

1. Deformed-Diaphragm Type Acceleration Gage. This gage consists of a lead disk or diaphragm whose edges are placed firmly against the ship part accelerated. Acceleration produces deformation of the central area of the disk. The disk is, of course, protected from the pressure wave in air.

2. Weakened-Plug Type Acceleration Gage. This gage consists of a cylinder or plug of Bakelite or other material; the plug has been weakened near the base, so that when the base is accelerated, the remainder of the plug may be broken off. By using large numbers of plugs of various strengths, acceleration values in the range from 100 to 1500 G may be determined readily.

3. Compressed-Spring Acceleration Gage, Putty-Recording Type. This gage consists of several units, each consisting of an inertia member, a spring, and a recorder. The springs have various degrees of stiffness. When the target vessel is moved suddenly, each spring (in contact with the target vessel) moves and tends to urge its corresponding inertia member to move also. Whether or not a given inertia member is moved is recorded by a pin capable of indenting a block of putty. By noting which inertia members actually moved, the acceleration value is thus "bracketed."

4. Compressed-Spring Acceleration Gage, Optical-Recording Type. This gage is similar in operating principle to the one decribed immediately above. However, it measures the three orthogonal components of acceleration, and the extents of compression of the several springs are determined by means of light beams which are recorded on photographic film.

5. Indentation-Type Acceleration Gage. This gage consists of an inertia member which, when accelerated, pushes the sharp "feet" of its supporting links into a block of aluminum. Acceleration is computed from the depths of the holes pressed in the block of aluminum.

6. Bent-Reed Type Acceleration Gage. This gage consists of

a graded series of reeds, each rigidly attached at one end and carrying at the free end an inertia member. When the assembly of reeds is accelerated, the reeds bend; the deflections, recorded by scribers on waxed paper, are indicative of the acceleration experienced.

E. Roll and Pitch. Because it was expected that pressure waves and water waves might cause severe roll or pitch of the target vessels, instruments were provided to record such ship motions. Principal means of determining roll and pitch are indicated below:

1. Camera. Cameras on island towers and on some of the target vessels themselves served to record roll and pitch of the target vessels.

2. Gyroscope Roll and Pitch Recorder. This device records roll and pitch data on a pen-and-ink recorder or on an oscillograph recorder.

3. Pendulum-Type Roll and Pitch Recorder. In this device scribers record roll and pitch data on rotating aluminum disks.

F. Temperature Rise. Temperature rise produced in target vessels was measured by maximum recording thermometers. Temperature rise produced on exposed surfaces was measured by panels painted with temperature-indicating paints, in which a color change in the paint indicates the highest temperature reached.

9.011 Preparations for Measuring Wave Phenomena.

A. Introduction. Prior to the Tests it was felt by some that the waves produced might cause important damage to target vessels or beach installations. Also, it was known that "full-scale experiment" data were much needed to show just how to interpret model basin experiments in terms of results produced by atomic bombs. Consequently, extensive plans were made to study the waves produced at Bikini, particularly by Test B, the underwater explosion.

Besides straightforward wave-height measurements, measurements were made of the closely related quantities; water depth and bottom pressure.

Some of the principal instruments used are mentioned below. It is unfortunate that in Test B the majority of the wave measuring instruments located within 1/3 mi of the Zeropoint were damaged by the explosion and gave little usable data.

B. Camera. In measuring wave phenomena much reliance was placed on cameras. Many of them were of long focal length; many were synchronized by special radio signals. Some were mounted on island towers; others were mounted in airplanes. Some were of high-speed operation; some were used to produce stereo pairs. Photographs taken from the air were usually oblique photographs; but on B-Day many photographs were taken from almost directly overhead.

C. Fathometer on Target Vessel. Several fathometers rigidly attached to target vessels were used to record water depth. They included Type NK-6 portable fathometers mounted over the stern, and Type MNC fathometers (modified to have a 200-ft scale) mounted inboard. Their recorders were started and stopped by clocks.

D. Fathometer on Special Buoy. Several additional fathometers of Type NK-6 were mounted on buoys (empty Mark IV mine cases) designed for minimum roll under wave action and tethered from the sterns of target vessels. Each fathometer's transducer was suspended below the buoy and connected by a 200-ft cable to the recorder mounted in the target vessel.

E. Bottom-Pressure Gage, Recording Type. Several hand-started wave-pressure recorders ("turtles") were laid on the bottom of the Lagoon, about 500 yd apart, at ranges of from 1000 to 4500 yd from the intended Zeropoint. They were laid in two radial lines and were buoyed and interconnected to aid their recapture. Each unit weighed approximately 200 lb, had an 8-in. smoked circular chart rotated once per hour by a spring-wound clock, and employed a Bourdon-type pressure element giving full deflection for a head of 100 ft of water. A constricted section was included between the sea connection and pressure element to protect the element from the shock wave. Instrument cases were of half-inch steel.

Besides the hand-started instruments described above, several blast-started bottom-pressure recorders were used to measure pressure change as a function of time. Each instrument recorded for approximately one hour.

F. Bottom-Pressure Gage, Radio-Reporting Type. Several radio-reporting bottom-pressure gages were used to transmit by radio the bottom-pressure data obtained. Sono-buoys were used as the radio-reporting units.

G. Bottom-Pressure Recorder for Waves at Great Distance. Bottom mounted small-wave pressure recorders (inductiphone type) were installed near several islands of the Atoll and neighboring atolls to measure height and time-of-arrival of waves at great distance. Instruments operated for several hours after How Hour.

H. Beach Water-Height Gage, Electrical Type. Maximum height of waves reaching Bikini Island was measured by electrical type maximum height recorders installed on Bikini beach. These consisted of vertical pipes, 6 in. in diameter and 15 ft in height, driven into the beach. A series of electrical contacts spaced 6 in. apart extended vertically along the pipe, so that water rising to the level of a particular contact would permit electric current to flow, blowing the corresponding electrical fuse in the central terminal block and thus recording the wave height attained. Two sets, of 3 pipes each, were rigged at Bikini. Each set contained one pipe at mean low-water level, one 3 ft below mean low-water level, and one 3 ft above. A single pipe was placed well inland, near the center of the Island.

<u>I. Beach Water-Height Gage, Tin Can Type.</u> This gage consisted of a series of small open cans nailed to posts and trees. Cans were mounted at various heights. Height of highest cans filled with Lagoon water indicated maximum height of waves.

<u>J. Television.</u> Television cameras and transmitters were installed on several Bikini towers. Motion pictures were made of the images reproduced in receivers on Bikini and in airborne receivers.

9.012 Preparations for Measuring Cloud and Column Phenomena.

In measuring size, rate-of-growth, and demise of clouds and column produced by the explosions, principal reliance was placed on still and motion-picture photography, including high-speed photography. Special timing signals were included on some of the motion-picture films so that rate-of-growth data could be determined with great accuracy. Reliability of width and height estimates was assured by carefully recording the positions and focal lengths of the cameras and by including in the fields of view various objects, such as target vessels, of known distance, heading, and length.

The later courses of the radioactive clouds were followed by observers in airplanes equipped with Geiger counters.

No direct method was available for determining directly the amount of water in the B-Day column, the average height to which the water in the column was carried, or the energy represented by the column.

9.013 Preparations for Measuring Water Crater.

The attempt was made to measure the size of the water crater produced in Test B. The apparatus used consisted of a number of small rugged steel cylinders each enclosing a piece of unexposed photographic film. The cylinders were secured at 100-ft intervals to a 1000-ft length of 3/8-in. chain laid (on the bottom) radially from the Zeropoint. The chain was anchored at its inner end and attached to a buoy at its outer end. Formation of a crater in the water directly beneath Bomb B would presumably uncover various cylinders, thus exposing them to the intense gamma radiation from the bomb. Units never uncovered would, of course, remain shielded and their film would remain unexposed.

9.014 Preparations for Measuring the Bottom Crater.

Plans for measuring the bottom crater created by Bomb B called for determining the depth of the water accurately before and after the explosion. Changes in depth would indicate depth of crater. Bottom-sampling procedures were worked out also, and, of course, condition of the bottom was noted by divers sent down to examine sunken vessels.

9.015 Preparations for Determining Water Current and Other Oceanographic Phenomena.

Principally in order to be able to predict the regions and durations of significant concentrations of radioactive materials produced by Bomb B, studies were made of water currents in the Lagoon. In measuring currents use was made of current meters, current poles, drift bottles, and dye markers; careful advance attention was given to regions of ingress and egress of the water. Current patterns, Lagoon profiles, water mixing, and net rate of exchange of Lagoon water and open sea water were determined. Effects of winds were investigated also. Temperature gradients were measured with bathythermographs. Salinity and other chemical properties were investigated. Studies of the current regime were assisted by preliminary investigation, using a model of the Bikini Atoll and environs.

Plans for measuring the radioactivity of the water are discussed in a previous section of this chapter.

9.016 Preparations for Determining the Remote Detectability of Atomic Bomb Explosions.

A. Introduction. Early in the planning of Operation Crossroads it was realized that information of military and scientific value might be obtained by means of physical measurements made at great distances from the locale of the detonation. Principal interest lay in development of a feasible method for detecting and locating future atomic bomb explosions anywhere in the world. The remote measurements decided on included geophysical, meteorological, magnetic, ionospheric, and radioactivity observations, to be made at various sites throughout a considerable fraction of the world. (Many of the sites are indicated in Chap. 3.) The principal types of phenomena considered are discussed briefly below:

B. Tides. Arrangements were made at many remote sites in the Pacific for detecting any abnormalities in height of water.

C. Magnetic Field. Arrangements were made at several remote stations for detecting any appreciable change in the ambient magnetic field. Recording variometers of very high sensitivity were used.

D. Atmospheric Ionization. Arrangements were made at many remote stations for determining whether any appreciable changes occurred in the relationship between frequency of radio signals and reflection of the signals from ionized layers in the upper atmosphere.

Arrangements were made for studying radio transmission from one radio station to another located a considerable distance beyond -- but in line with -- the explosion area. It was thought that explosion-produced atmospheric ionization might attenuate the transmission.

The explosion area was studied by radar sets also, to determine whether any important amount of atmospheric ionization was produced.

E. Spherics. Arrangements were made at several points in Continental U. S. for detecting any spherics ("static") produced by the explosion.

F. Air Pressure. Arrangements were made at several stations for detecting any appreciable change in air pressure due to the explosions. Microbarographs were used.

G. Radioactivity in Air. Instruments were set up at a number of stations throughout the world for determining any increase in the radioactivity in the air. Geiger counters were used. Some were situated on the ground; others were carried to high altitude by radiosonde balloons.

H. Earth Shock. Many stations throughout the world were alerted to detect any appreciable earth shock.

9.017 Other Technical Preparations.

Preparations were made for recording the maximum temperature rise of the Lagoon water as a result of the explosions. Maximum recording thermometers were used.

Studies on the general physiography and geology of the Atoll were made in advance of the atomic bomb explosions.

Seismographic studies were made to: (1) see whether it was feasible to detect and locate the explosion point by seismographic measurements and triangulation; (2) determine velocity and character of the propagation of the seismic wave; (3) confirm the existence of a new type of seismic wave first detected in the Trinity Test; (4) obtain information as to the cause and nature of microseisms, important in connection with predicting and locating tropical storms.

To assist the interpreting of results on pressure, shock-wave velocity, optical radiation, etc., extensive aerological measurements were arranged. Many maximum and minimum thermometers, hygrothermographs, barographs, and psychrometers were used in the extensive aerological program referred to in Chap. 3 and described in detail in Ref. 210.

To show the effect of the explosion on airborne planes nearby, such planes were provided with instruments recording altitude, air speed, acceleration and time. In some instances engine performance was continuously recorded also.

FINDER

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Chapter 10

Execution of Test A

10.001 Introduction.

This Chapter describes the execution of Test A. It makes no attempt to cover the objects of the Test (see Chap. 2), organization, administration, nontechnical preparations, or rehearsal (see Chap. 3), or the technical results, which are covered in Chaps. 11 through 19.

10.002 Delivery of Bomb.

Bomb A, dubbed "Gilda," was put aboard the specially-prepared B-29 bombing plane "Dave's Dream," Aircraft No. 44-27354, at Kwajalein at approximately 1230, 30 June 46, Bikini local time (i.e., time in minus eleven time zone). Loading was facilitated by use of the specially-constructed loading ramp on the south side of the western end of the runway.

The men who boarded Dave's Dream were:

Maj. W. P. Swancutt	Airplane Commander
Brig. Gen. R. M. Ramey	Task Group 1.5 Commander
Col. W. J. Blanchard	Air Attack Commander
Capt. W. C. Harrison, Jr. (Army)	Co-Pilot
Maj. H. H. Wood	Bombardier
Col. J. R. Sutherland	Bomb Commander
Ens. D. L. Anderson	Weaponeer
Mr. L. D. Smith	Weaponeer
Capt. Paul Chenchar, Jr. (Army)	Radar Observer
Maj. W. B. Adams	Navigator
Lt. R. M. Glenn (Army)	Flight Engineer
Corp. R. M. Modlin	Scanner
Corp. H. B. Lyons	Scanner
Tech. Sgt. J. W. Cothran	Radio Operator

At the originally scheduled hour of takeoff, 0534, Dave's Dream was standing on the loading ramp, loaded and ready. The go-ahead signal from Commander JTF-1 was relayed at 0542 from MT. MCKINLEY to ALBEMARLE moored at Kwajalein and was immediately transferred to the Commander Task Group 1.5. Three minutes later, at 0545, Dave's Dream taxied down the ramp towards the takeoff position at the west end of the runway. Takeoff occurred at 0555.

At 0547 How Hour had been postponed by Commander JTF-1 because of cloud conditions at Bikini and because clear weather was expected at a later time. X-Ray hour, the scheduled time of arrival at stations, was changed from 0649 to 0719. The postponement, besides allowing time for the cloud coverage to lessen, made it possible for the command aircraft of Task Group 1.5 (which had arrived on station at 0527 at an altitude of 23,000 ft) to make a last minute reconnaissance upwind to increase the reliability of predictions as to the cloud cover which would exist at Bikini at How Hour.

Plans had previously been made to shorten the route of Dave's Dream to the target area to compensate for any delay in takeoff. However, 3 min after takeoff, notice of the 30-min postponement of How Hour was received. Therefore Dave's Dream proceeded as originally briefed. It reached bombing altitude over Wotho Atoll, and arrived over the target area at 0803. It made the prescribed wind run to Orbit Point Baker. The Bomb Commander and weaponeers completed their final tests and adjustments.

The one dry run began at 0820. During this run, the Edgerton flasher on NEVADA was seen clearly. Also the radar beacon at Bikini was picked up 50 mi away and was used to time the approach and maintain the desired course, which was 045° (True). The bombardier's recognition of the target center was further aided by the white turrets of NEVADA. Visibility was excellent. Simulated release was at 0831. The dry run was considered successful. Ballistic wind data (13[illegible] mi/hr from 128° True) were obtained by radio from MT. MCKINLEY.

At 0849, CUMBERLAND SOUND reported ready for the live bombing run; whereupon Commander JTF-1 gave the command to start.

Meanwhile Dave's Dream had started back to Orbit Point Baker. It began the live run at 0850, bearing 225° (True), distance 50 nautical miles from target. It passed the Initial Point bearing 225° (True), at a distance 35 nautical miles from target, and continued on to target.

At 0900, the cloud coverage, which had been 0.2 to 0.3 at 0830, had decreased to 0.1 to 0.2. The wind encountered was 11½ mi/hr from 14[illegible]° (True).

Bombing altitude of (nominally) 29,000 ft was maintained; calibrated indicated air speed was 190 statute mi/hr; true air speed was 299 mi/hr. The following is a quotation from Part III, Sec. E, of Air Operations Report of Operations Crossroads by Commander Task Group 1.5: "The bombardier corrected for wind and bomb weight, and added a small compensation for the inherent tendency to hit short with KN bombs. (KN bombing tables were used in all computations.)"

The report referred to above continues (p. 79): "Timing was very nearly perfect. Accepting actual release as the basis for measuring errors, the 10-min signal was 14 sec late, the 5-min signal was 12 sec late, the 2-min signal was 8 sec late, and the 1-min signal was only 3 sec late. Release occurred at 0859:46, exactly 14 sec early."

At the instant the bomb was released, the bombardier broadcast "Bomb Away, Bomb Away."

A report by the Air Attack Commander stated: "The Bomb Commander watched the bomb clear the airplane and stated it did not hit any part of the Bomb Carrier."

A few seconds after release of the bomb (bomb-bay doors closed within 3 to 8 sec) the pilot executed a 150° level turn to the left and then executed a shallow dive, losing 1000 ft while increasing calibrated indicated air speed to 240 mi/hr. The shock wave was felt in the plane 84 sec after release and the secondary wave was felt immediately thereafter. Neither affected control of the plane.

"Dave's Dream" returned to Orbit Point Baker and from there went directly to base at Kwajalein, landing without incident.

Eggleston Eight, the F-13 photographic plane, rendezvoused with "Dave's Dream" at 0803. It accompanied Dave's Dream on all runs, maintaining position 1000 ft to the right. It took motion pictures of Dave's Dream and of the bomb falling (35-mm black and white film, Serial No. Cr. 18248). It then broke away, turning 150° to the right, photographing the bomb throughout its fall and photographing the explosion.

Pictures taken from Dave's Dream gave a pictorial record of the line of flight prior to the drop and of the drop of the bomb throughout the first few seconds.

10.003 Detonation.

The bomb detonated at 34 sec ± 5 sec after 0900 (1 July 46) Bikini local time, which is 34 sec ± 5 sec after 1700 (30 June 46) EST and 34 sec ± 5 sec after 2200 (30 June 46) GCT.

The bomb fell for 48.1 sec ± 0.3 sec before detonating.

Altitude of the bomb at Mike Hour was 518 ft with a probable error of plus or minus 10 ft. (Source: Ref. 300-11)

Final data as to the latitude and longitude of the actual Zeropoint were not available in the office of the Technical Director by 1 Nov 46.

Surface atmospheric conditions in the Lagoon at Mike Hour were as follows:

Dry bulb temperature	30° C	(86° F)
Wet bulb temperature	25.3°C	(77.5°F)
Pressure	1012.2 millibars	(29.888 in. of mercury)
Relative humidity	68 percent	
Dew Point	23.3° C	(74° F)
Wind	East Northeasterly 8 knots	
Visibility	15 mi	
Velocity of Sound	350 m/sec	

Wind direction and velocity at 0905 were as follows:

Altitude (ft)	Direction (° True)	Velocity (knots)
0	80	8
1000	130	15
2000	130	13
3000	130	13
4000	130	14
5000	140	14
6000	140	15
7000	120	15
8000	120	11
9000	130	11
10,000	-	-
12,000	120	7
14,000	100	9
15,000	100	7
16,000	070	8
18,000	320	2
20,000	330	4
22,000	210	5
24,000	150	16
25,000	180	8
28,000	120	4
30,000	340	6
35,000	340	2
40,000	070	8
45,000	030	26

At 1020 temperature and humidity values at various altitudes were as indicated below:

Altitude (ft)	Temperature (°C)	Relative Humidity (percent)
Surface	28	80
10,000	28	80
15,000	21	80
20,000	12	60
30,000	-5	90
35,000	-12	90

10.004 Status of Target Vessels.

Table 10.1 shows the A-Day, Mike Hour positions and aspects of the target vessels.

Fig. 10.1 is a chart of the Test-A target array showing positions of target vessels relative to projected Zeropoint on A-Day at Mike Hour.

Table 10.2 shows the conditions of target vessels within 1000 yd of the Zeropoint as regards fuel and ammunition loads:

10.005 Status of Other Targets.

(A) Airborne Targets. Four Army and three Navy drones were airborne on A-Day at Mike Hour. They were located as follows at Mike Hour:

Drone	Altitude (ft)	Approx. Slant Distance from Zeropoint (Nautical Miles)	Bearing from Zeropoint (° True)
B-17 Fox	24,000	20	270
B-17 George	30,000	30	045
B-17 How	18,000	30	045
B-17 Love	13,000	30	045
F6F Yellow Dog	10,000	20	312
F6F Blue Dog	15,000	20	312
F6F White Dog	20,000	20	312

(B) Shore Targets. Eighteen landing craft were exposed on the beach at Bikini between 5500 and 6000 yd from Zeropoint. These included:

Type	Quantity	Identifying No.
LST	1	133
LCI	2	615,620
LCT	4	414,812,1175,1237
LCM	5	2,3,4,5,6
LCVP	6	7,8,9,10,11,12

(C) Other Targets. Two PB2Y-5E Coronado seaplanes were on the surface between 2600 and 3350 yd from the Zeropoint, bearing approximately 270° True.

One pontoon bridge was moored to the stem of the ARDC-13.

10.006 Status of Personnel.

Practically the entire complement of personnel in the Bikini area observed the explosion. Many persons wore special protective goggles; others took the prescribed precautionary measures of facing away from the Zeropoint and covering their eyes with their forearms.

Nearly all of the personnel were aboard the non-target surface vessels; some, including special observers, were aboard aircraft. No persons were aboard the target vessels.

Nearest non-target vessels, between 11.7 and 15 nautical mi from Zeropoint, were:

Appling	Haven
Artemis	Henrico
Avery Island	Laffey
Barton	Mt. McKinley
Begor	O'Brien
Burleson	Walke
Cumberland Sound	Wharton
	Whiting

The nearest manned planes at Mike Hour were B-29 Dave's Dream and F-13 (photographic plane) Eggleston Eight, both at an altitude of approximately 28,000 ft. The shock wave produced no more noticeable effect than the planes' encountering normal propeller wash.

TABLE 10.1. RELATIVE POSITIONS OF TARGET VESSELS ON A-DAY AT MIKE HOUR.

Vessel	Range fm Burst to Bow (Yd)	True Bearing of Bow from Burst		Relative Bearing of Burst from Bow		Coordinates of Vessel from Burst (Yd)				Distance from Burst to Nearest Part of Vessel (Yd)	Direction of Burst from Vessel
						Bow		Stern			
						X	Y	X	Y		
Battleships & Cruisers		deg	min	deg	min						
Arkansas, BB 33, 562*	779	54	40	150	15	632 E	443 N	457 E	427 N	621	Stbd. Qtr.
New York, BB 34, 573	1729	107	46	59	04	1643 E	539 S	1499 E	419 S	1547	Stbd. Qtr.
Nevada, BB 36, 583	792	99	24	192	09	777 E	134 S	595 E	139 S	615	Stern
Pennsylvania, BB 38, 608	1743	150	03	208	22	841 E	1505 S	664 E	1397 S	1541	Port Qtr.
Pensacola, CA 24, 586	898	82	33	172	45	883 E	111 N	704 E	109 N	710	Stern
Salt Lake City, CA 25, 586	1018	136	23	228	00	698 E	743 S	501 E	745 S	895	Port Qtr.
Nagato, JAP BB,	1015	112	22	198	44	935 E	393 S	692 E	371 S	782	Port Qtr.
Sakawa, JAP CL,	607	81	58	177	40	595 E	91 N	411 E	61 N	420	Stern
Prinz Eugen, IX 300,	1194	298	04	343	40	1041 W	588 N	1218 W	737 N	1194	Bow
Aircraft Carriers											
Saratoga, CV 3, 910	2563	129	52	183	10	1951 E	1661 S	1713 E	1480 S	2263	Stern
Independence, CVL 22, 619	699	125	27	223	34	563 E	410 S	365 E	436 S	560	Port Qtr.
Destroyers											
Lamson, DD 367, 344	768	36	38	92	43	455 E	619 N	369 E	671 N	762	Stbd. Beam
Conyngham, DD 371, 344	3247	113	58	154	26	2955 E	1345 S	2883 E	1259 S	3145	Stbd. Qtr.
Mugford, DD 389, 341	2802	114	03	173	43	2549 E	1164 S	2455 E	1106 S	2690	Stern
Talbot, DD 390, 341	1245	90	12	139	20	1239 E	13 S	1159 E	62 S	1163	Stbd. Qtr.
Mayrant, DD 402, 341	3614	220	00	280	18	2358 W	2740 S	2448 W	2686 S	3614	Port Beam
Rhind, DD 404, 341	1012	07	27	61	14	135 E	1004 N	49 E	1067 N	1012	Stbd. Bow
Stack, DD 406, 341	1332	340	56	31	39	427 W	1264 N	511 W	1333 N	1332	Stbd. Bow
Wilson, DD 408, 341	1480	324	29	24	06	851 W	1209 N	941 W	1265 N	1480	Stbd. Bow
Hughes, DD 410, 348	1028	96	32	192	10	1019 E	123 S	907 E	105 S	922	Stern
Anderson, DD 411, 348	636	180	57	247	43	13 W	638 S	117 W	589 S	598	Port Beam
Mustin, DD 413, 348	2262	112	46	169	05	2079 E	893 S	1979 E	824 S	2147	Stern
Wainwright, DD 419, 348	2159	307	05	342	55	1713 W	1314 N	1778 W	1404 N	2159	Port Bow
Submarines											
Skipjack, SS 184, 299	1204	149	36	211	55	599 E	1043 S	512 E	996 S	1122	Port Qtr.
Searaven, SS 196, 310	1856	47	37	126	30	1381 E	1239 N	1279 E	1259 N	1798	Stbd. Qtr.
Tuna, SS 203, 299	2194	31	10	75	53	1159 E	1863 N	1103 E	1935 N	2194	Stbd. Bow
Skate, SS 305, 311'6"	483	111	27	211	29	447 E	179 S	344 E	196 S	400	Port Qtr.
Apogon, SS 308, 311'6"	1031	165	38	201	04	252 E	1006 S	189 E	916 S	940	Stern
Dentuda, SS 335, 311'6"	1948	72	15	101	23	1856 E	581 N	1814 E	664 N	1930	Stbd. Beam
Parche, SS 384, 311'6"	1366	199	55	270	55						
Pilotfish, SS 386, 311'6"	2506	49	27	68	19	1889 E	1647 N	1779 E	1690 N	2506	Stbd. Beam
Landing Craft											
LST 52, 328	1539	30	42	82	02	793 E	1319 N	713 E	1381 N	1532	Stbd. Beam
LST 220, 328	3272	09	33	34	06	578 E	3221 N	533 E	3322 N	3272	Stbd. Bow
LST 545, 328	4067	10	53	130	07						
LST 661, 328	2320	21	11	60	11	838 E	2162 N				

* Length of Ship in Feet

TABLE 101. RELATIVE POSITIONS OF TARGET VESSELS ON A-DAY AT MIKE HOUR. (con't)

Vessel	Range fm Burst to Bow (Yd)	True Bearing of Bow from Burst		Relative Bearing of Burst from Bow		Coordinates of Vessel from Burst (YD)				Distance from Burst to Nearest Part of Vessel (Yd)	Direction of Burst from Vessel
						Bow		Stern			
						X	Y	X	Y		
Landing Craft (con't)		deg	min	deg	min						
LCI 327, 159*	2481	92	48	134	45	2477 E	141 S	2445 E	104 S	2441	Stbd. Qtr.
LCI 329, 159	2892	94	56	59	35	2879 E	273 S	2909 E	233 S	2892	Stbd. Bow
LCI 332, 159	2265	95	44	193	56	2252 E	246 S	2189 E	253 S	2217	Stern
LCI 549, 159	4553	92	19	135	19	4549 E	185 S				
LCT 745, 120	3807	273	07	323	07						
LCT 816, 120	1361	79	48	152	54	1331 E	235 N	1298 E	245 N	1318	Stbd. Qtr.
LCT 818, 120	1498	71	59	89	30	1429 E	451 N	1413 E	501 N	1495	Stbd. Beam
LCT 874, 120	2544	62	00	113	45	2256 E	1174 N	2222 E	1201 N	2519	Stbd. Qtr.
LCT 1013, 120	4067	285	48	351	48						
LCT 1078, 120	3279	57	52	116	47	2792 E	1719 N	2755 E	1740 N	3254	Stbd. Qtr.
LCT 1112, 120	3904	56	19	105	12	3266 E	2138 N	3232 E	2167 N	3886	Stbd. Beam
LCT 1113, 120	4217	55	39	109	27	3582 E	2409 N	3564 E	2431 N	4195	Stbd. Beam
LCM 1,						863 E	31 S	839 E	23 S		
Merchant Craft											
Gilliam, APA 57, 426	47	329	53	22	33	28 W	44 N	139 W	127 N	47	Bow
Banner, APA 60, 426	1312	112	39	164	15	1209 E	513 S	1094 E	427 S	1180	Stern
Barrow, APA 61, 426	1334	255	56	310	46	1298 W	311 S	1416 W	233 S	1334	Port Bow
Bladen, APA 63, 426	2910	156	17	216	02	1145 E	2673 S	1025 E	2606 S	2810	Port Qtr.
Bracken, APA 64, 426	2160	143	36	190	56	1272 E	1749 S	1155 E	1677 S	1842	Port Qtr.
Briscoe, APA 65, 426	1712	120	25	181	11	1469 E	876 S	1345 E	806 S	1575	Stern
Brule, APA 66, 426	1094	67	37	129	58	1011 E	407 N	889 E	471 N	1005	Stbd. Qtr.
Butte, APA 68, 426	1973	250	38	307	38						
Carlisle, APA 69, 426	429	228	38	281	44	328 W	279 S	443 W	193 S	429	Port Bow
Carteret, APA 70, 426	1757	79	52	125	11	1732 E	294 N	1636 E	394 N	1677	Stbd. Qtr.
Catron, APA 71, 426	1895	132	52	185	38	1382 E	1296 S	1269 E	1213 S	1764	Stern
Cortland, APA 75, 426	3140	242	52	299	52						
Crittenden, APA 77, 426	594	282	00	344	57	581 W	127 N	708 W	191 N	594	Bow
Dawson, APA 79, 426	853	257	02	311	30	835 W	183 S	946 W	103 S	853	Port Bow
Fallon, APA 81, 426	1414	140	06	203	05	899 E	1093 S	775 E	1026 S	1290	Stern
Fillmore, AFA 83, 426	2568	151	02	206	00	1229 E	2256 S	1115 E	2173 S	2453	Port Qtr.
Gasconade, APA 85, 426	2687	245	41	302	41						
Geneva, APA 86, 426	3162	160	00	217	30	1059 E	2979 S	939 E	1905 S	3062	Port Qtr.
Niagara, APA 87, 426	3407	162	45	222	20	983 E	3261 S	865 E	3189 S	3318	Port Qtr.
Concrete Drydocks & Barges											
YO 160	638	90	48	198	22	637 E	11 S	520 E	51 S	520	Port Qtr.
YOG 83	1134	56	09	137	20	949 E	621 N	825 E	639 N	1041	Stbd. Qtr.
ARDC 13	835	180	55	272	06	28 W	834 S	160 W	944 S	827	Port Beam

* Length of Ship in Feet.

TOP SECRET

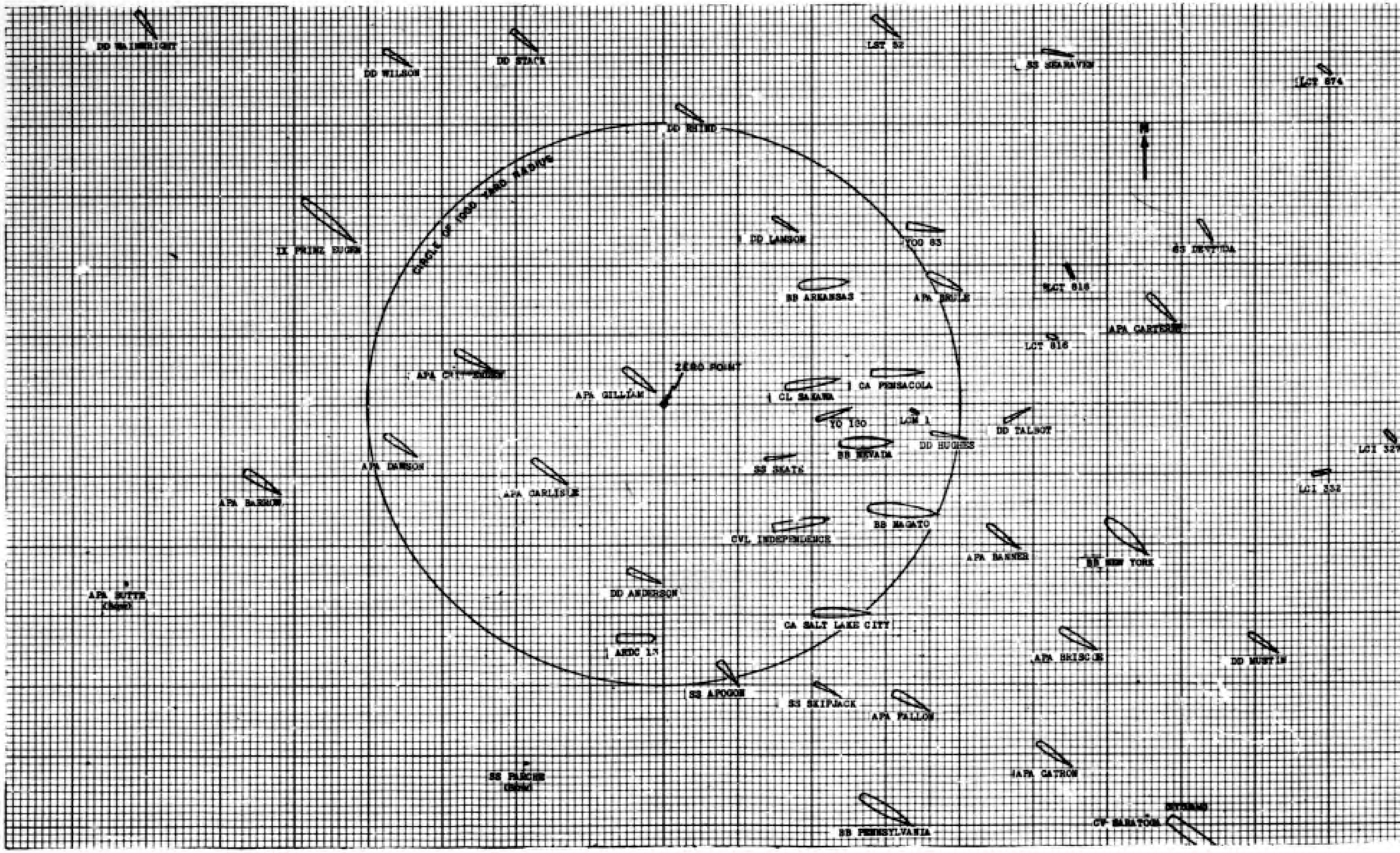

FIGURE 10.1. TEST-A TARGET ARRAY [INNER PORTION] SHOWING POSITIONS OF TARGET VESSELS RELATIVE TO PROJECTED ZEROPOINT ON A-DAY AT MIKE HOUR.

Table 10.2

Test-A Fuel and Ammunition Loads on Target Vessels Within 1000 Yd.

Note: Percentages refer to percentages of normal load (abbreviated N). Normal load ordinarily means approximately 95 percent of capacity. M indicates minimum load, ordinarily approximately 10 percent of capacity.

Target Vessel	Fuel Load (percent)	Ammunition Load (percent)
Battleships & Cruisers		
Arkansas	50	50
Nagato	15	M
Nevada	33	67
Pensacola	15	67
Sakawa	33	0
Salt Lake City	M	M
Aircraft Carriers		
Independence	33	67
Destroyers		
Anderson	N	N
Hughes	15	67
Lamson	50	50
Rhind	50	50
Submarines		
Apogon	50	50
Skate	33	67
Attack Transport Merchant Type		
Brule	M	M
Carlisle	N	N
Crittenden	N	N
Dawson	50	50
Gilliam	50	50
Other Craft		
ARDC - 13	0	0
YOG - 83	0	0
YO - 160	0	0

Other major equipment aboard vessels included:

- Special Test Ammunition
- Tanks, guns, trucks
- 73 Navy aircraft

10.007 Re-entry.

Re-entry in Bikini Lagoon proceeded according to schedule.

A. Re-entry by Drone Planes. Drone planes played an important part in the "re-entry." Shortly after Mike Hour, at 0908, an Army B-17 drone plane entered the cloud at 24,000 ft followed in a few minutes by three other B-17 drones, at altitudes of 30,000, 18,000, and 13,000 ft. Navy F6F drones flew thru the cloud at 20,000, 15,000, and 10,000 ft. After having successfully collected air samples, the drones returned to base. The samples were then transferred to Kwajalein for analysis.

B. Re-entry by Drone Boats. To help control the LCVP drone boats, four TBM planes with drone boat conning officers and radiological safety monitors aboard, were launched from SAIDOR a few minutes after Mike Hour. Shortly afterwards, BEGOR (drone boat control vessel) approached the Lagoon (outside Bikini-Enyu reef) for visual control of the drone boats.

At 0944 the first LCVP drone started towards the target array; the other started soon afterwards. The first LCVP reached the target center at 1045 and began picking up water samples at 1101; it evacuated the area at 1136. By 1300 a number of water samples had been transferred to MOALE, which was soon speeding to Kwajalein where the samples were analyzed.

C. Re-entry by Manned Planes. Two radiological reconnaissance PBM's, "Charlie" and "Dog," were the first manned planes to fly into the immediate vicinity of the target array. Leaving their stations shortly after Mike Hour, they moved to positions 5 nautical miles upwind from the Zeropoint; at 0952 "Charlie" began traversing the target area in parallel sweeps, "Dog" following at 1055. At 1310 "Dog" flew directly over the Zeropoint at 3000 ft.

D. Re-entry by Manned Vessels. At 0947 radiological clearance was given to BARTON to go to the Lagoon entrance and for the (Wave 1) 6 PGM's of the radiological safety party to follow her. Shortly afterward, Commander JTF-1 directed Wave 7A (Task Unit 1.2.8; APPLING, ARTEMUS, and HENRICO with the radiological safety party's 20 LCPL's aboard) to enter the Lagoon and lower the LCPL's. By 1050 the PGM's had entered the Lagoon. By 1125 Wave 7A had completed launching the LCPL's, which thereupon entered the Lagoon.

The FALL RIVER anchored on station in Enyu Channel at 1202 and served as harbor entrance control vessel. By 1430 the Lagoon was declared safe for the entrance of all vessels. Vessels of the Technical Group 1.1 entered at 1425; the MT MCKINLEY entered at 1500.

Salvage vessels (Waves 3 and 4) entered at 1300 and by 1402 were engaged in fighting fires aboard some ships.

By sundown on A-Day, 18 vessels had been reboarded by initial boarding teams although no ships' teams had been placed aboard. Some fires persisted.

10.008 Sinkings.

Salient data on sinkings and times of sinking are recorded below: (See Chap. 13 for details).

GILLIAM (APA-57) sank within about one minute after Mike Hour.

ANDERSON (DD-411) by 0908 had rolled over and sunk.

CARLISLE (APA-69) had sunk by 0940. She was burning vigorously amidships shortly after Mike Hour.

LAMSON (DD-367) sank between 1400 and 1700. She capsized to starboard (towards the Zeropoint) and was seen floating bottom up until about 1400.

SAKAWA sank at 1044 one day after A-Day. A fire burned aboard her until the morning after A-Day. Progressive flooding took place. Attempts were made to beach her, but soon after being taken in tow, she keeled over to port and sank by the stern.

Chapter 11

Summary of Results of Test A

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Chapter 11

Summary of Results of Test A

11.001 Introduction.

Bomb A detonated 518 ft above the surface of Bikini Lagoon at 34 sec after 0900, 1 July 46, Bikini Local Time. Seventy target vessels were exposed to the explosion; their positions were as shown in Table 10.1 of Chap. 10.

Some of the most significant results are summarized very briefly in the following sections. More extensive summaries are presented in the following 8 chapters.

11.002 Energy Release.

The amount of energy released was "normal" for an atomic bomb of the Nagasaki type; a total of 8.0 X 10^{20} ergs of energy was released, equivalent to the total amount of energy released in the exploding of 19.1 kilotons of TNT.

11.003 Damage to Vessels.

A total of 5 vessels sank as a result of the explosion; they were situated in the range: 50 to 760-yd horizontal distances from the projected Zeropoint. (Distances are measured to nearest point of vessel.)

Six (non-sunk) vessels were immobilized; they were situated at ranges of 560 to 920 yd.

11.004 Other Damage.

Tanks and guns suffered no appreciable loss of military efficiency at ranges greater than 600 yd. Light vehicles and other light structures were severely damaged out to 1200 yd.

Electronic equipment and instruments were seriously damaged out to 1200 yd.

Packaged ammunition remained undamaged at ranges greater than 1000 yd.

Baled and packaged clothing was damaged, primarily by fires, up to 2000 yd; tires were undamaged (except for superficial scorching) at and beyond 600 yd; plastics were damaged at distances as great as 2000 yd.

Nonperishable packaged food at 500 yd was cleared for consumption by four days after A-Day.

11.005 Injury to Animals and Plants.

More than 50 percent of the test animals situated within 1000 yd of the Zeropoint died; between 15 and 30 percent of the test animals in the annulus from 1000 to 2000 yd died; 5 to 15 percent of the test animals outside 2000 yd died.

Air blast (including primary and secondary effects) was the principal cause of injury leading to immediate "loss of military efficiency" of the test animals; however, many of the animals killed by the air blast received lethal dosages of gamma radiation.

Principal cause of delayed deaths was gamma radiation.

11.006 Pressure Data.

Values of peak pressure in air just above the Lagoon surface were: 2000, 53, 10.5, 4.8, and 3.1 psi gage at horizontal distances of 0, 500, 1000, 1500, 2000 yd from the projected Zeropoint. At 26,800-ft altitude and 11,500 yd slant range the peak pressure was 0.17 psi gage.

The duration of the positive pressure pulse was 0.46 sec and 0.75 sec at horizontal distances of 500 and 1000 yd, respectively.

The shock wave in air had an initial "slant range" velocity of over 14,000 ft/sec; at 1/2 mile slant range the wave had a velocity of approximately 1800 ft/sec.

Peak pressure in closed (surviving) vessels never exceeded 2.5 psi gage.

11.007 Radiation and Radioactivity.

The directly-determined value for total amount of energy emitted by the detonation as optical radiation (including ultraviolet, visible, and infrared light) in the spectral range from 3400 to 24,000 A was 1.7 X 10^{21} ergs, although this figure (corresponding to 40 kilotons of TNT) is obviously far too large. At 12 nautical miles the peak illumination was approximately 10 times greater than is produced by noon summer sun and skylight.

The fireball had a maximum surface temperature of roughly 200,000° K; the radius of the fireball was 110 ft at 1 millisecond after Mike Hour and 800 ft at 1 second after Mike Hour.

The great majority of the gamma radiation reaching target vessels reached them within the first 10 seconds. Cumulative gamma radiation dosages at exposed locations at 600, 1000, 1500, and 2000 yd from the projected Zeropoint were 9000, 1800, 220, and 28 roentgens, respectively. The dosage at 1350 yd was approximately 400 roentgens (lethal).

Neutron dosages were not lethal at horizontal distances greater than 550 yd.

11.008 Other Results.

By 150 sec after Mike Hour the cloud had reached an altitude of nearly 5 mi; its maximum width was 9000 ft, and a thin cap, presumed by some to be an ice cap, had formed. By 400 sec after Mike Hour the cloud had reached 7 mi.

Radioactivity from the explosion was detected at many remote sites, including Continental U. S., several days later.

11.009 Correlations.

The following Table presents estimates by the JTF-1 Technical Historian as to the ranges at which specified loss of military efficiency during the first hour after Mike Hour is probable.

Extent of Immediate Loss of Military Efficiency	Range (yd)		
	Typical Ship	Typical Crew	Ship and Crew in Combination
Very Serious	900	700	900
Serious	1000	800	1020
Moderate	1300	900	1300
Slight	1500	1000	1500

Obviously, the weak link as regards immediate loss of military efficiency is the ship itself. If resistance of stacks and (antenna-supporting) masts could be appreciably increased, a reduction of roughly 100 yd could be effected in the range of immediate loss of combined military efficiency.

Shock wave in air is the cause of greatest immediate (i.e., first hour) loss of military efficiency of ships themselves. Shock wave in air competes with optical radiation as the principal cause of immediate loss of military efficiency of crews per se which are situated outside 900 yd. In the annulus from 600 to 900 yd gamma radiation is the principal cause of loss of military efficiency of crews per se; and within 600 yd neutron and gamma radiations compete as the principal cause. Radiation intensities at ranges less than 550 yd are of reduced interest since ships within 550 yd will ordinarily be sunk.

A typical surface combatant vessel will probably be sunk by a pressure wave in air having a peak pressure greater than 35 psi gage; it will probably suffer very serious immediate loss of military efficiency when subjected to a peak pressure greater than 25 psi gage; peak pressures of 20, 15, and 10 psi gage will probably produce serious, moderate, and slight immediate losses of military efficiency, respectively.

Peak pressures of 25 and 4 psi gage will probably produce (respectively) very serious and slight immediate losses of military efficiency of personnel.

11.010 Discussion.

The Operation had no important shortcomings; but these minor imperfections deserve mention: The bomb detonated 710 yd from the intended Zeropoint, for cause unknown; the timing signal relied on for starting a number of the instruments was sent out a few seconds late, as a result of two errors by the timing signal operator; a number of instrument-starting black boxes failed to operate satisfactorily, for a combination of reasons.

From the technical point of view as well as from the operational point of view the Test was very successful. Graded damage was produced in ships of many types; graded injury was produced in animals of several types; and the principal physical phenomena (causative factors) were evaluated with reasonably high accuracy. A firm basis was established for determining the vulnerability of ships and crews to air bursts of atomic bombs, and for improving future designs and tactics.

Chapter 12

Detonation and Energy Release, Test A

Outline

Chapter 12

Detonation and Energy Release, Test A

12.001 General Appearance

(Only a brief account of the appearance of the detonation is given here. Later chapters discuss in detail the fireball and condensation cloud.)

Test-A Mike Hour (detonation instant) occurred on 1 July 46 at 34 sec (plus or minus 5 sec) after 0900, Bikini local time.

A very intense flash of light was emitted by the bomb during the first two seconds after detonation.

The fireball, beginning its existence in the very process of disintegration of the bomb, was clearly in view during the first 2 sec. Then, for 2 or 4 sec, it was partially or wholly obscured from view by the condensation cloud. At about 5 to 8 sec after Mike Hour it came into view again. It grew, rose, and -- by 10 to 20 sec after Mike Hour -- had lost itself in the rapidly rising mushroom.

The condensation cloud, sometimes called the Wilson Cloud, formed immediately after the shock wave outstripped the fireball (i.e., at about 1.5 or 2 sec after Mike Hour) and grew rapidly. It was highly luminous at first because of the fireball located at its center. By 5 sec after Mike Hour the condensation cloud had become toroidal. By 10 to 15 sec after Mike Hour it was broken up; fragments disappeared rapidly, due to evaporation.

The mushroom top evolved from the fireball and from the air above the fireball; it assumed its characteristic mushroom appearance within 20 sec after Mike Hour. Within one minute it had reached an altitude of 13,000 ft, and it eventually reached a height of 40,000 ft. When the mushroom top reached approximately 18,000 ft, (i.e., after approximately 2 min) it was sheathed in a thin cap composed, perhaps, of ice crystals. No rain fell. The cloud drifted with the wind, lost its mushroom shape and was lost to the sight of the observers off Bikini within approximately 1 hr.

All but an insignificant fraction of the fission products rose in the mushroom, whose radioactivity was still detectable at a distance of 70 mi.

Within a few seconds of the passage of the suction wave past a given target ship, a black cloud, often larger than the ship itself, could be seen above the ship. (The cloud is believed to have been composed of soot and dirt shaken loose from — and sucked out of — the stacks and other superstructure paraphernalia.)

Some fires were detected by observers.

Water waves were not discernible to observers.

The sound of the explosion did not reach the 20-mi-distant non-target vessels for nearly 2 min; it was barely audible.

12.002 Total Energy Release.

The best value for the total amount of energy released by the explosion is 8.0×10^{20} ergs, which is equal to the total amount of energy released in the explosion of 19.1 kilotons of TNT. This figure is based on the radio-chemical method described in Chap. 5. (Source: Oral statement 25 Oct 46 by Technical Director.) The probable error is: 10 percent. (Source: Ref. 300-22, p.4)

12.003 Partial Energy Release.

Collateral values of equivalent-TNT-tonnage are given below. They are not ordinarily strictly indicative of the total amount of energy released, but are indicative only of that portion of the energy manifest in the shock wave, or some other phenomenon. Their significance is discussed in Chap. 5 and also in Refs. 500, 300-4, and 300-18.

Parameter Measured	Types of Gage Used	Equivalent-TNT-Kilotons	Source (Ref.No.)
Pressure in air	Diaphragm strain	20	300-4
Pressure in air	Foil	21	300-4
Pressure in air	Can and Drum	20	300-4
Pressure in air	Airborne Condenser	17	300-4
Duration of positive pulse in air	De Juhasz	20	300-4

Wind Velocity	Pipe	20	300-4
Shock wave velocity	Chronograph recorder	21	300-4
Rate of increase in radius of fireball	O'Brien camera	21	300-4
Total optical radiation	Bolometer	40(very rough)	300-18

12.004 Utilization of Energy.

No data were available by 1 Nov 46 as to the utilization or apportioning of the energy among nuclear radiation, shock wave, column, gravity waves, and heat.

No more than 10 percent (or possibly 20 percent) of the energy went into potential energy of the column. (Source: Ref. 302)

Chapter 13

Damage to Vessels, Test A

Outline

Chapter 13

Damage to Vessels, Test A

13.001 Introduction.

This Chapter includes a brief, preliminary, and a highly tentative summary of the significant damage suffered by the principal target vessels in Test A. In no sense are the data final, nor are they necessarily representative of considered judgments by the Director of Ship Material.

Much more extensive summaries, of considerably increased reliability, are now in preparation by DSM, and will be available soon. These forthcoming summaries, here referred to as Ref. 450, will include also a number of monographs on such subjects as flooding, fire, welding, piping. In addition, they will present detailed tabulation of damage index numbers and charts showing damage as a function of distance. Final conclusions and evaluations of ship damage should be made only after consulting these reports.

The generalization included below should be regarded merely as interim estimates by the JTF-1 Technical Historian.

Considered first is damage to ships as wholes; then damage to hulls (exclusive of superstructures, masts, antennas, and stacks); then damage to superstructures; and so on. In nearly every instance, damage means: damage indicative of loss of military efficiency.

13.002 Loss of Military Efficiency.

Note: The term military efficiency as used in this Chapter refers only to the military efficiency of the vessels themselves, irrespective of crews.

A. Very Serious Loss of Military Efficiency.

1. Ships Sunk. Five ships were sunk in Test A. The ships were:

Vessel	Horizontal Distance from Zeropoint (yd)
GILLIAM (APA-57)	50
SAKAWA (ex-Jap CA)	420
CARLISLE (APA-69)	430
ANDERSON (DD-411)	600
LAMSON (DD-367)	760

2. Ships Immobilized. Six (non-sunk) ships were immobilized. They were located at ranges of 400 to 1000 yd from the actual Zeropoint. Their immobilization was ordinarily a result of damage to stacks and boilers. The ships were:

INDEPENDENCE (CVL-22)	560
NEVADA (BB-36)	615
ARKANSAS (BB-33)	620
PENSACOLA (CA-24)	710
SALT LAKE CITY (CA-25)	895
HUGHES (DD-410)	920

B. Serious Loss of Military Efficiency. Among the ships suffering short or long term serious loss of military efficiency were:

SKATE (SS-305)	400
YO-160	520
CRITTENDEN (APA-77)	595
ARDC-13	825
DAWSON (APA-79)	855
RHIND (DD-404)	1012
SARATOGA (CV-3)	2265
LST-52	1530

C. Moderate Loss of Military Efficiency. Among the ships suffering short or long term moderate loss of military efficiency were:

TALBOT (DD-390)	1165
BARROW (APA-61)	1335
PENNSYLVANIA (BB-38)	1540
NEW YORK (BB-34)	1545

D. Slight Loss of Military Efficiency. Damage to electronic equipment caused slight loss of military efficiency as far out as approximately 1800 yd.

E. Range versus Loss of Military Efficiency. The ranges given below for various specified degrees of loss of military efficiency are such that, at a given horizontal range, it is probable (probability greater than 50 percent) that a surface ship of unspecified type and orientation will suffer -- at least temporarily -- the indicated degrees of loss of military efficiency.

Extent of (at least temporary) Loss of Military Efficiency	Range (yd)
Very serious	900
Very serious (but disregarding boiler damage)	600
Serious	1000
Moderate	1300
Slight	1500

13.003 Damage to Hulls.

A. Introduction. This section discusses damage to hulls, here considered to include decks, sides, and bottoms of vessels. (Damage to superstructure, i.e., structure above the weather deck, is treated in Sec. 13.004; damage to masts is considered in Sec. 13.005 and damage to stacks in Sec. 13.007.) In most cases damage to hulls of surviving vessels was light and was not accompanied by flooding. Damage to the hulls of the sunken vessels was severe; it consisted usually of tears in the side shell plating and, of course, flooding.

B. Description of Damage.

1. Battleships. NEVADA (615 yd), battleship closest to the actual Zeropoint, received only minor hull damage; no flooding occurred. As to battleships in general, main decks were dished at distances as great as 780 yd, and at 1540 yd there was no significant hull damage.

2. Cruisers. Severe hull damage (including a tear along the centerline at the stern) caused the sinking of the Japanese light cruiser, SAKAWA (420 yd). (SAKAWA was of considerably lighter construction than PENSACOLA or SALT LAKE CITY and her hull damage cannot be compared with damage to the U. S. Cruiser.) The light aircraft carrier INDEPENDENCE (560 yd), suffered severe hull damage; her hull was blown in and there was buckling of bulkheads, reducing watertightness. (INDEPENDENCE had a modern cruiser hull which, although lighter than the riveted hulls of PENSACOLA and SALT LAKE CITY, was partly of welded construction.) PENSACOLA (710 yd) suffered severe dishing of deck structure. Dishing of the same order but less

serious occurred on SALT LAKE CITY (895 yd). PRINZ EUGEN (of heavier and more modern construction than PENSACOLA or SALT LAKE CITY) experienced practically no hull damage at 1195 yd.

3. Destroyers. ANDERSON (600 yd) sustained severe hull damage causing sinking (probable hole in plating on port side). Similarly, LAMSON (760 yd) sank (probable hole in starboard side). HUGHES (920 yd) survived without flooding, suffering some dishing and bulging of her main deck. RHIND (1010 yd), TALBOT (1165 yd), STACK (1330 yd), and WILSON (1480 yd) had very minor dishing of their hulls. MUSTIN (2145 yd) was not damaged.

4. Submarines. SKATE (400 yd) had her outer hull badly stripped and crumpled; her pressure hull suffered substantially no damage and did not experience flooding. APOGON (940 yd) was undamaged.

5. Attack Transports. GILLIAM (45 yd), APA closest to the actual Zeropoint, sank within one minute; she was badly ruptured, crumpled, and twisted almost beyond recognition. CARLISLE (430 yd) sank within 40 min; her side shell plating contained two very long breaks and severe dishing also. CRITTENDEN (bow-on, at 595 yd), surviving APA nearest to the actual Zeropoint, suffered severe dishing and deflection of deck; she was not flooded. Her bow-on orientation may have saved her from being sunk.

6. Aircraft Carriers. Damage to the sides and bottom of INDEPENDENCE (560 yd) has been discussed in the paragraph on cruisers, since her hull was very similar to that of a light cruiser. SARATOGA (2265 yd) was not damaged.

7. Other Vessels. YO-160 (520 yd) had its concrete deck spalled, with bent reinforcing bars exposed in numerous places. There was no flooding. LST-52 (1530 yd) suffered light dishing of starboard shell plating. ARDC-13 (825 yd) was cracked just below the waterline permitting seepage into two compartments.

C. Loss of Military Efficiency.

1. Battleships. Battleships suffered no loss of military efficiency due to hull damage.

2. Cruisers. Japanese cruiser SAKAWA (420 yd) sank in 25 hr due to hull damage (the ship's force, if uninjured, could possibly have saved her). INDEPENDENCE (light cruiser hull, 560 yd) suffered serious loss of military efficiency due to loss of watertightness above the waterline; she would have suffered progressive flooding in heavy seas. PENSACOLA (710 yd) suffered serious loss of military efficiency due to loss of watertightness above the second deck, and

her longitudinal structural strength was slightly impaired. She could have been made sufficiently operable by ships' force to return to port for repair, but would not have been an effective fighting unit without such repair. SALT LAKE CITY (895 yd) suffered some hull damage above her second deck.

3. Destroyers. Destroyers ANDERSON (600 yd) and LAMSON (760 yd) sank as the result of hull damage. (ANDERSON sank in 8 min; LAMSON sank in approximately 5 hr.) HUGHES (920 yd) suffered slight loss of military efficiency.

4. Submarines. There was no impairment of military efficiency of submarines due to damage to pressure hull.

5. Attack Transports. GILLIAM (45 yd) and CARLISLE (430 yd) sank. CRITTENDEN (595 yd) suffered serious loss of military efficiency and would have been unable to operate as a transport without extensive repairs to her hull.

D. Distance versus Damage Relationship. The Test-A distance versus hull damage data are presented in Table 13.1. The distances given are (as elsewhere in this Chapter) horizontal distances in yards from the projected actual Zeropoint to the nearest part of the vessel. In most cases the distances figure given represents the greatest radius* at which damage of indicated severity actually occurred to target vessels on A-Day. In the "Negligible Damage" column, however, the value given for each type of vessel is the range of that vessel (suffering negligible damage) which was nearest the Zeropoint. Similarly the "Nearest Surviving Ship" column gives for each type of ship the range of that (surviving) ship which was nearest the Zeropoint. In using the Table, it is convenient to bear this rule in mind: when comparing vulnerability of ships of different type (with respect to damage of specified type and severity), or when comparing vulnerability of different parts of a ship, higher numbers indicate greater vulnerability.

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* If the "sample" of ships had been greater, instances would presumably have occurred where even greater ranges could have been found for damage of specified type. On the other hand, we may now have instances where ships at lesser ranges did not suffer damage of the indicated severity. Thus the ranges here presented are not intended to be ranges for which the probability value equals 50 percent or any other percentage; they are merely observed greatest ranges. On the other hand, they are probably fairly close, in many cases, to "probability-equals-50 percent" ranges given in other sections.

E. Ship Type versus Damage Relationship. It is tentatively suggested that hull vulnerability of principal types of target ships increased in the following order: submarines (least vulnerable); battleships; and attack transports and destroyers (most vulnerable). Attack transports might have proved more vulnerable had it not been for the fact that CRITTENDEN, at 595 yd, happened to be almost exactly bow-on, and survived. The most representative range for (probable) major hull damage is of the order of 600 yd.

F. Engineering Consequences of Damage. In most cases where the hull was breached, flooding occurred, causing sinking. Damage to hulls not involving flooding had no appreciable effect on the operation of propulsion machinery. ARDC-13 (825 yd), a concrete drydock, suffered some flooding due to cracks to her hull; her standard pumps (not actually installed prior to the test) could have controlled the flooding readily.

G. Mechanism of Producing Damage. In all or nearly all cases hull damage was attributable to the pressure wave in air.

13.004 Damage to Superstructure.

(Mast damage is discussed in Sec. 13.005 and stack damage is discussed in Sec. 13.007.)

A. Introduction. The superstructure of the target ships were especially vulnerable, i.e., to the air burst.

Damage appeared typically in the form of dishing or other distortion. INDEPENDENCE (560 yd) had large holes blown in the sides enclosing her hangar deck. Plating of 10-lb weight (1/4 in. thick) or heavier in the superstructure of ships, at 600 yd or more, did not suffer much deformation.

B. Description of Damage.

1. Battleships. All of the battleships received superstructure damage ranging from extensive distortion at 620 yd, to heavy dishing at 780 yd, and light dishing at 1550 yd. There were no battleships beyond this range.

2. Cruisers. Japanese light cruiser SAKAWA (420 yd) had her superstructure badly crushed. Both U. S. cruisers received superstructure damage. PENSACOLA (710 yd) suffered extensive distortion whereas SALT LAKE CITY (895 yd) suffered heavy dishing. There were no U. S. cruisers beyond this distance. German heavy cruiser PRINZ EUGEN (1195 yd) suffered light dishing of her superstructure.

TABLE 13.1. GREATEST RANGE AT WHICH DAMAGE OF INDICATED SEVERITY WAS PRODUCED IN TEST A
(Range is horizontal distance in yards from projected aeropoint to nearest part of ship)

Ship Type and Distances	Innermost Surviving Ship	Sunk	HULL (DECKS, SIDES, BOTTOM) Major Damage	HULL Moderate Damage	HULL Minor Damage	HULL Negligible Damage	SUPERSTRUCTURE Major Damage	SUPERSTRUCTURE Moderate Damage	SUPERSTRUCTURE Minor Damage	SUPERSTRUCTURE Negligible Damage	Masts and Antennae Major Damage	Masts and Antennae Minor Damage	Boilers Major or Moderate Damage	Boilers Minor or No Damage	Stacks or Uptakes Major or Moderate Damage	Stacks or Uptakes Minor or No Damage	Miscellaneous Machinery Major or Moderate Damage
Battleships 615, 620, 780, 1540, 1550	615 (NEVADA)	No Cases	No Cases	No Cases	780 (NAGATO)	1540 (PENN.)	620 (ARKANSAS)	780 (NAGATO)	1550 (NEW YORK)	No Cases	780 (NAGATO)	1540 (PENN.)	1550 (NEW YORK)	No Cases	1550 (NEW YORK)	No Cases	620 (airplane cranes)
Cruisers (U.S.) 560, 710, 895	560 (INDEPENDENCE)	No Cases	560 (INDEP.)	895 (S.L.C.)	No Cases	No Cases	710 (PENSACOLA)	895 (S.L.C.)	No Cases	No Cases	895 (S.L.C.)	No Cases	895 (S.L.C.)	No Cases	895 (S.L.C.)	No Cases	610 — (airplane crane)
Cruisers (Foreign) 420, 1190	1190 (EUGEN)	420 (SAKAWA)	420 (SAKAWA)	No Cases	No Cases	1190 (EUGEN)	420 (SAKAWA)	No Cases	1190 (EUGEN)	No Cases	1190 (EUGEN)	No Cases	420 (SAKAWA)	1190 (EUGEN)	420 (SAKAWA)	1190 (EUGEN)	Less Than 1190
Destroyers 600, 760, 920 1010, 1165, 1330, 1480, 2150	920 (HUGHES)	760 (LAMSON)	760 (LAMSON)	920 (HUGHES)	1480 (WILSON)	2150 (MUSTIN)	760 (LAMSON)	1010 (RHIND)	1480 (WILSON)	2150 (MUSTIN)	1165 (TALBOT)	1480 (WILSON)	1010 (RHIND)	1165 (TALBOT)	1165 (TALBOT)	1480 (WILSON)	Less Than (HUGHES) 920
Submarines 400, 940	400 (SKATE)	No Cases	No Cases	No Cases	400 (SKATE)	940 (APOGON)	400 (SKATE)	No Cases	No Cases	940 (APOGON)	400 (SKATE)	940 (APOGON)	No Cases	No Cases	No Cases	No Cases	400 (SKATE New Buoyancy Vent Valves)
Aircraft Carrier (Light) 560	560 (INDEPENDENCE)	No Cases	Same as U.S. Cruisers				560 (INDEP.)	No Cases	No Cases	No Cases	560 (INDEP.)	No Cases	No Cases	No Cases	560 (INDEP.)	No Cases	560 (elevators Swept Overboard; Catapult Machinery Inoperable)
Aircraft Carrier (Heavy) 2260	2260 (SARATOGA)	No Cases	Same as Battleships				No Cases	No Cases	No Cases	2000	No Cases	No Cases	No Cases	No Cases	No Cases	No Cases	2260 (elevator jammed)
Attack Transports 50, 430, 595, 855, 1005, 1180, 1290, 1335, 1575, 1675, 1760	595 (CRITTENDEN)	430 (CARLISLE)	595 (CRITTENDEN)	855 (DAWSON)	1575 (BRISCOE)	1675 (CARTERET)	595 (CRITTENDEN)	1005 (BRULE)	1575 (BRISCOE)	1675 (CARTERET)	1180 (BANNER)	1675 (CARTERET)	430 (CARLISLE)	855 (DAWSON)	595 (CRITTENDEN)	855 (DAWSON)	1005 (BRULE Davits inoperable)
Explanation of Column Headings			Flooding or Severe Buckling of Plates	Heavy Dishing	Light Dishing	Distance of Nearest Ship Suffering Negligible Damage	Demolished or Extensive Distortion	Heavy Dishing	Light Dishing	Distance of Nearest Ship Suffering Negligible Damage.	Damage Rendering Antennae and Radar Inoperable	Minor Damage	Loss of Boiler Power	Minor or no Damage	Impairment of Boiler Operation	Minor or no Damage	Machinery Damage Impairing Military Efficiency

TOP SECRET

3. Destroyers. Destroyers, being lightly constructed, suffered much superstructure damage. The extensive distortion zone extended out to 760 yd, heavy dishing to 1010 yd and light dishing was experienced at 1480 yd.

4. Submarines. The superstructure on SKATE (400 yd) was very extensively damaged -- in fact, badly stripped and crumpled. APOGON (940 yd) received no superstructure damage.

5. Aircraft Carriers. The superstructure on INDEPENDENCE (560 yd) was extensively damaged. Her flight deck was badly warped and buckled, and the sides enclosing her hangar deck were blown through. SARATOGA (2265 yd) received no appreciable superstructure damage.

6. Attack Transports. Damage to APA superstructure ranged from extensive distortion (to bow-on CRITTENDEN) at 595 yd to heavy dishing at 1005 yd and very light dishing as far out as 1290 yd.

7. Other Vessels. Extensive damage to the superstructure of concrete oil barge YO-160 was experienced at 520 yd.

C. Loss of Military Efficiency.*

1. Introduction. There were no cases in which superstructure damage per se put ships out of action. However, extensive superstructure damage in many cases impaired the military efficiency of the ship. Damage to superstructure often caused loss of watertightness, malalignment of gun batteries, and damage to radar and communication antennas.

2. Battleships. Damage to light superstructure plating on NEVADA (615 yd) caused damage to fire control antennas and moderate loss of military efficiency. (See Sec. 13.005 on Masts.) No other battleships suffered appreciable loss of military efficiency due to superstructure damage.

3. Cruisers. PENSACOLA (710 yd) suffered slight loss of seaworthiness due to failure of topside doors and hatches; SALT LAKE CITY (895 yd) also suffered some superstructure damage. No other surviving cruisers suffered appreciable loss of military efficiency due to superstructure damage.

4. Destroyers. There was no very notable loss of military efficiency of surviving destroyers due to superstructure damage. (See however, Sec. 13.005 on Damage to Masts and Sec. 13.007 on Damage to Stacks and Uptakes.)

5. Submarines. Extensive superstructure damage to SKATE

(400 yd) seriously impaired her military efficiency. APOGON (940 yd) suffered no significant loss of military efficiency due to superstructure damage.

6. Aircraft Carriers. Flight deck of INDEPENDENCE (560 yd) was put out of commission involving complete loss of military efficiency. Hangar deck also was wrecked, sides were blown through, and a fire in the stern added to the serious loss of military efficiency. The superstructure of SARATOGA (2265 yd) was undamaged.

7. Attack Transports. Superstructure damage probably did not seriously impair the military efficiency of the surviving APA's.

8. Other Vessels. There was no loss of the military efficiency of the oil barges and concrete drydock due to superstructure damage.

D. Distance versus Damage Relationship. The distance versus damage data for superstructure damage are presented in Table 13.1.

E. Ship Type versus Damage Relationship. Superstructure vulnerability appears to be approximately the same for the principal types of target ships. The approximate maximum radii for superstructure damage of specified severity were: for major damage, 700 yd; for moderate damage, 1000 yd; and for minor damage, 1500 yd. Not included in this comparison are submarines, since there was only one instance of superstructure damage to this type of ship. Destroyer superstructures were somewhat more vulnerable than the rest.

13.005 Damage to Masts.

A. Introduction. Damage to masts was especially serious in Test A because of the resulting damage to radio and radar antennas connected to the masts.

B. Description of Damage. Damage to masts was evidenced by breakage or bending accompanied by damage to communication or radar antennas.

C. Loss of Military Efficiency by Damage to Masts.

1. Introduction. The chief loss of military efficiency resulting from mast damage was failure of search radar, fire control radar, and radio. In cases of radar antenna damage, repairs could not be made by the ship's force at sea.

2. Battleships. All the antennas on NEVADA (615 yd) were

blown down due to mast failure; this caused serious loss of military efficiency. Similarly, ARKANSAS (620 yd) and NAGATO (780 yd) suffered complete loss of antennas and thus suffered serious loss of military efficiency. There was slight reduction of military efficiency on PENNSYLVANIA (1540 yd) which suffered minor antenna damage due to mast failure; NEW YORK (1545 yd) experienced no antenna damage.

3. Cruisers. PENSACOLA (710 yd), SALT LAKE CITY (895 yd), and PRINZ EUGEN (1195 yd) suffered serious reduction in military efficiency due to mast failure.

4. Destroyers. The military efficiency of destroyers out to 1160 yd was seriously impaired due to mast failure.

5. Submarines. SKATE (400 yd) suffered serious loss of military efficiency due to mast damage and complete loss of antennas.

6. Aircraft Carriers. INDEPENDENCE (560 yd) suffered serious loss of military efficiency due to mast damage and complete loss of antennas.

7. Attack Transports. APA's out to 1005 yd suffered moderate loss of military efficiency due to mast and antenna damage.

D. Distance versus Damage Relationship. The distance versus damage data for mast damage are presented in Table 13.1. Only mast damage leading to damage to antennas is recorded.

E. Ship Type versus Damage Relationship. Mast damage occurred on ships of all types. In general, damage occurred (minor in some cases) out to 1500 yd. The approximate maximum radius for major mast damage was 1100 yd for nearly all types of ships.

F. Engineering Consequences of Damage. As indicated in a previous paragraph, the engineering consequence of mast damage was failure of radar and radio antennas, rendering radar and radio equipment inoperable.

G. Mechanism of Producing Damage. Mast damage was caused by the pressure wave in air.

13.006 Damage to Boilers.

Boiler damage in Test A was limited principally to casings, brickwork, oil burners, smoke periscopes, smoke pipes, and uptakes. In general, external fittings and boiler pressure parts suffered no damage. In all cases of boiler damage mentioned in this Section, there was loss of boiler power.

B. Description of Damage.

1. Battleships. All U. S. battleships suffered major boiler damage. NEVADA (615 yd) had side-casing panels on all six boilers blown out. ARKANSAS (620 yd) suffered damage to boiler casings and minor damage to brickwork. PENNSYLVANIA's boilers were inoperable (1540 yd) due to bulging of boiler side-casing panels. NEW YORK (1545 yd) had its boiler casings partially blown off. Boilers on NAGATO (780 yd) were undamaged.

2. Cruisers. Both U. S. cruisers suffered major boiler damage. PENSACOLA (710 yd) suffered damage to boiler casings on all eight of her boilers. SALT LAKE CITY (895 yd) suffered damage to boiler casings as well as to brickwork. No boiler on either of these cruisers could have been used without extensive repair. INDEPENDENCE (560 yd) experienced negligible damage to her boiler casings. She could have steamed after moderate repairs.

3. Destroyers. HUGHES (920 yd) suffered bulging of boiler casings. Her boilers could not have been operated without major repairs. There was damage to boiler brickwork on RHIND (1010 yd) but boiler casings were tight. Two of her boilers were in satisfactory condition for steaming. No other destroyers suffered significant boiler damage.

4. Attack Transports. CRITTENDEN (595 yd), surviving APA nearest Zeropoint, had the boiler casing of one boiler split. Both boilers were in operable condition. No other surviving APA's suffered significant boiler damage.

C. Loss of Military Efficiency.

1. Introduction. In general, boiler damage resulted in loss of power accompanied by reduced speed and impaired operation of ordnance and machinery, involving serious loss of military efficiency.

2. Battleships. The military efficiency of NEVADA (615 yd) was very seriously reduced (to 10 percent or less) by loss of power due to boiler damage. As this ship had steam steering, this also was out of commission. Temporary repairs by ship's force could be made in 12 to 24 hr to enable her to steam at a very slow speed. ARKANSAS (620 yd) would have been dead in the water due to boiler damage until temporary repairs had been effected (5 to 10 hr). Her military efficiency was very seriously reduced. PENNSYLVANIA (1540 yd) would have lost all motive power for a short interval after which she could have steamed at greatly reduced speed with serious reduction

in military efficiency. NEW YORK (1545 yd) suffered moderate loss of military efficiency due to boiler damage which would have prevented full power operation for 12 hr.

3. Cruisers. INDEPENDENCE (cruiser hull, 560 yd) suffered no loss of military efficiency due to boiler damage. (However, damage to stacks and uptakes would have immobilized her for a day or more. See Sec. 13.005.) PENSACOLA (710 yd) was immobilized due to boiler damage: her military efficiency was seriously reduced (to 5 percent or less). SALT LAKE CITY (895 yd) would have been immobilized for 72 hr or more, with very serious reduction of military efficiency. PRINZ EUGEN (1195 yd) had no loss of military efficiency as the result of boiler damage.

4. Destroyers. Destroyers out to 1010 yd suffered very serious loss of military efficiency due to loss of power resulting from boiler damage. (Power on destroyers out to 1165 yd would have been reduced due to stack and uptake damage.)

5. Attack Transports. CRITTENDEN (595 yd) was the only surviving APA to suffer loss of military efficiency due to boiler damage. Her military efficiency was moderately impaired.

D. Distance versus Damage Relationship. The distance versus damage data for boiler damage are presented in Table 13.1. The "Major Damage" column gives greatest radii at which boiler damage occurred and resulted in loss of power.

E. Ship Type versus Damage Relationship. Boilers on battleships and U. S. cruisers of older designs were found to be especially vulnerable to damage. Boiler damage occurred on battleships out to 1550 yd and on the outermost U. S. cruiser at 895 yd. The Japanese battleship NAGATO (780 yd) and the German heavy cruiser PRINZ EUGEN (1195 yd) did not receive boiler damage. Significantly, the boilers on the modern carrier INDEPENDENCE (light cruiser hull) were undamaged at 560 yd, although this ship suffered severe stack damage. Boilers on destroyers were not appreciably damaged beyond 1010 yd, and boilers on attack transports were not damaged beyond 430 yd.

The difference in vulnerability of boilers on ships of different types is believed to be due partly to difference in stack construction, and partly to differences in stack height, protection, and kind of metal used. Stacks in older ships were in many instances riveted whereas the stacks on the destroyers and attack transports were often of welded construction. See Sec. 13.007 for discussion of stack and uptake damage.

F. Engineering Consequences of Damage. Boiler damage was accompanied by loss of power for propulsion and for operation of ship's machinery and ordnance.

G. Mechanism of Producing Damage. Boiler damage was often caused by air pressure going down stacks. Where the stack was swept away or torn, the pressure wave probably reached the boilers directly through the uptakes.

13.007 Damage to Stacks and Uptakes.

A. Introduction. Damage to stacks and uptakes was significant because of the effect on boiler operation. In each case of stack or uptake damage discussed in this Section, there was loss of boiler power regardless of whether or not there was actual damage to the boiler itself.

B. Description of Damage.

1. Battleships. NEVADA (615 yd) had her outer stack dished and distorted and the top of her inner stack carried away. Uptakes below her main decks were carried away. ARKANSAS (620 yd) had her stack completely demolished. No other battleships suffered stack damage.

2. Cruisers. All four stacks on INDEPENDENCE (light cruiser hull, 560 yd) were demolished. PENSACOLA (710 yd) and SALT LAKE CITY (895 yd) suffered major stack damage. German heavy cruiser PRINZ EUGEN (1195 yd) did not suffer stack damage.

3. Destroyers. Destroyers suffered serious stack damage out to 1165 yd.

4. Attack Transports. APA stacks were seriously damaged only out to 595 yd.

C. Loss of Military Efficiency.

1. Introduction. In all cases of major stack damage there was loss of boiler power accompanied by reduced speed and impaired operation of ordnance and machinery, involving loss of military efficiency. In general, temporary stack repairs could be made by ship's force at sea.

2. Battleships. All U. S. battleships suffered serious stack damage which would have impaired boiler operation independently of whether the boilers themselves had been damaged. (Actually, boilers on all battleships were damaged.) Their military efficiency was very seriously reduced due to stack damage.

3. Cruisers. INDEPENDENCE (light cruiser hull, 560 yd) suffered very serious loss of military efficiency due to stack and uptake damage. (She would have been immobilized for a day or more. However, her biolers were undamaged. Both PENSACOLA (710 yd) and SALT LAKE CITY (895 yd) would have suffered very serious loss of military efficiency due to stack damage. Both PENSACOLA and SALT LAKE CITY suffered boiler damage.)

4. Destroyers. Whereas boiler damage on destroyers extended only to 1010 yd, stack and uptake damage very seriously reduced their military efficiency and would have prevented full boiler power on destroyers out to 1165 yd.

5. Attack Transports. Stack damage to CRITTENDEN (595 yd) reduced boiler power and very seriously impaired her military efficiency. (CRITTENDEN's boilers were also damaged at this distance.)

D. Distance versus Damage Relationship. The distance versus damage data for stack damage are presented in Table 13.1. In all cases of major or moderate stack damage there was loss of boiler operation, but not necessarily boiler damage.

E. Ship Type versus Damage Relationship. It is tentatively suggested that stack vulnerability increased in the following order: attack transports (least vulnerable), battleships, cruisers, destroyers (most vulnerable). However, the differences may in some cases be due to relatively extraneous factors.

F. Engineering Consequences of Damage. Serious stack damage impaired boiler operation.

G. Mechanism of Producing Damage. Stack damage was due to the pressure wave in air.

13.008 Damage to Miscellaneous Machinery.

A. Introduction. With the exception of damage to boilers, uptakes, and stacks, damage to machinery on surviving vessels was confined to topside deck auxiliaries.

B. Description of Damage.

1. Battleships. Both the NEVADA (615 yd) and ARKANSAS (620 yd) suffered damage to airplane cranes.

2. Cruisers. The airplane crane on PENSACOLA (710 yd) was rendered inoperative.

3. Destroyers. There was no significant damage to destroyer auxiliary machinery.

4. Aircraft Carriers. INDEPENDENCE (560 yd) lost forward and after elevator platforms. SARATOGA (2265 yd) suffered temporary jamming of her only elevator for airplanes.

5. Attack Transports. Boat davits on CRITTENDEN (595 yd) and DAWSON (855 yd) were rendered inoperative.

C. Loss of Military Efficiency.

1. Battleships and Cruisers. NEVADA, ARKANSAS, and PENSACOLA were unable to launch their planes. This caused a slight loss of military efficiency.

2. Destroyers. There was no significant loss of military efficiency.

3. Aircraft Carriers. Neither INDEPENDENCE nor SARATOGA could operate as carriers, both losing use of elevators. (This constituted very serious immediate loss of military efficiency; however, SARATOGA's elevator was readily repairable.)

4. Attack Transports. Failure of boat davits on CRITTENDEN and DAWSON greatly impaired efficiency in unloading troops. (This constituted serious loss of military efficiency.)

D. Distance versus Damage Relationship. The distance versus damage data for damage to auxiliary machinery are presented in Table 13.1. Only damage to vital auxiliary machinery is considered.

E. Engineering Consequences of Damage. Failure of airplane cranes and elevators temporarily prevented raising or lowering of aircraft. Failure of boat davits prevented raising or lowering of small boats.

F. Mechanism of Producing Damage. Damage to auxiliary machinery was caused by the pressure wave in air.

13.009 Damage to Electrical Equipment.

Exposed electrical equipment and instruments suffered serious damage within a radius of approximately 900 yd. Interior electrical equipment suffered little or no damage other than damage associated with distortion of supporting structure or with secondary fires. In general, damage to electrical equipment did not cause serious loss of military efficiency.

13.010 Damage to Ordnance Equipment.

The air burst did very little serious damage to ordnance equipment in the target vessels. This is not surprising since ordnance gear is, of course, designed to withstand gun blast.

Because of boiler damage major power-operated ordnance equipment was inoperative on NEVADA (615 yd), ARKANSAS (620 yd), INDEPENDENCE (560 yd), PENSACOLA (710 yd), SALT LAKE CITY (895 yd), and HUGHES (920 yd). RHIND (1010 yd) would probably have been adversely affected also, because of interference by smoke as a result of loss of her stacks.

In general damage to radar antennas (see Sec. 13.005) greatly reduced the accuracy of fire control systems within 1000 yd of the Zeropoint.

Modern rangefinders withstood the explosion with no internal damage. Rangekeepers suffered light damage. Ammunition withstood the heat and blast without change. Torpedoes, mines, and depth charges were not detonated. Twelve torpedo warheads on INDEPENDENCE (560 yd) burned. External heat on the torpedo air flasks caused explosion of some of the flasks.

13.011 Damage to Electronic Equipment.

Electronic equipment sustained major damage on 11 vessels and minor damage on 17 additional vessels. Damage to antennas of radio and radar equipment accounted for over 90 percent of the equipment rendered inoperative. (See Sec. 13.005.) Vacuum tubes and other delicate components protected by enclosures generally remained undamaged. The pressure wave in air was responsible for the majority of damage.

Major damage was confined to an area within 1000 yd of the Zeropoint. Minor damage occurred at ranges between 1000 yd and 1500 yd. Electronic equipment on ships beyond 2500 yd was in most cases undamaged.

13.012 Damage from Fires.

Flash heat scorching was apparent on surfaces normal to the blast up to a distance of about 3700 yd. Many fires started in jute and manila cordage. The burlap wrapping of Army Quartermaster material ignited in some instances. There was considerable evidence that many incipient fires within a radius of 1500 yd of the Zeropoint were extinguished by the air pressure wave immediately following the flash.

There were no oil fires either in the water or in target ships (except on SAKAWA). In general, damage from fires did not cause serious loss of military efficiency, except in the case of the INDEPENDENCE.

13.013 Damage from Ammunition Explosions.

There was no evidence of loss of ships or serious damage to ships through ammunition explosions. However, there probably was an explosion on ANDERSON (600 yd).

13.014 Relationship Between Ship Orientation and Damage.

The relationship between ship orientation and damage has not yet been evaluated. Unfortunately, there were few cases where damaged ships located at equal distances from the actual Zeropoint had contrasting orientations.

Chapter 14

Other Damage, Test A

Outline

Section

Chapter 14

Other Damage, Test A

14.001 Introduction.

Damage to material and equipment which are more or less standard on Naval vessels has been discussed in the previous chapter. The present chapter describes the damage to special test equipment exposed on the target vessels. More detailed information may be obtained from Ref. 420-2 and 410-7.

14.002 Damage to Vehicles, Guns, and Searchlights.

Tanks and guns suffered no impairment of operational efficiency at or beyond 600 yd. Inspection plate fastenings failed at ranges as great as 1500 yd. Unarmored vehicles, searchlights, and airplane structures were severely damaged at ranges up to 1200 yd and suffered minor damage at ranges from 1200 to 2500 yd.

14.003 Damage to Electronic Equipment.

Electronic equipment and instruments were seriously damaged at ranges up to 1200 yd and slightly damaged at ranges of 1200 to 2500 yd. Small, compact equipment was superior to large units in blast resistance.

14.004 Damage to Special Ammunition and Pyrotechnics.

Packaged ammunition remained undamaged at distances greater than 1000 yd. At 1000 yd pyrotechnics in thin cases but otherwise unshielded were unaffected. Some exposed items, such as wrapped propelling charges and mortar powder increments in plastic casings, were destroyed at distances up to 2100 yd.

14.005 Damage to Food, Clothing, Etc.

Baled and packaged clothing was damaged, primarily by fire, at distances up to 2000 yd. Certain insecticides, soaps, powders, and solutions retained appreciable amounts of radioactivity over a relatively long period of time. Nonperishable packaged food at 500 yd was cleared for consumption by four days after A-Day.

14.006 Damage to Rubber Materials.

Dense and thick rubber objects such as pneumatic tires and electrical cables were undamaged (except for superficial scorching) at and beyond 600 yd. Thin rubber coatings and objects of sponge rubber were charred at a distance of 600 yd.

14.007 Damage to Plastics.

Plastics were damaged at distances as great as 3000 yd. All kinds of plastics were highly susceptible to heat flash, which produced fusing. Laminated panels of glass and metal separated because of breakdown of the plastic-bonding compound.

14.008 Damage to Surfaces.

Thin surface layers of paper or paint were superficially scorched at 600 yd, but the general relationship between scorching and distance is not yet clear. Ranges of scorching and blistering of paint were irregular, depending on composition, color, and method of application and also (probably) on the extent of thermal radiation screening by steam or fog suddenly produced just above the surface of the Lagoon. Baked paint on Army equipment withstood heat much better than the flat paint on decks and bulkheads of ships.

14.009 Metallurgical Damage.

Radiation caused no perceptible metallurgical damage.

Chapter 15

Injury to Animals, and Plants, Test A

Outline

Chapter 15

Injury to Animals and Plants, Test A

15.001 Introduction.

Estimates and generalizations presented below, although very rough, are believed to be qualitatively accurate. The majority of the estimates and generalizations have been made by the JTF-1 Technical Historian, based on information contained in Ref. 410-5 and additional information obtained informally from the DSM Naval Medical Research Section and the 013 Radioactivity Section.

It is to be borne in mind that predictions as to ranges at which personnel would be injured are not necessarily based on data on injury to test animals, but may be based on measured values of pressure, gamma radiation, etc., and on previously determined values of lethal dosage.

15.002 Animal Census.

Presented below are the salient statistics on animals used in the Test.

Type of Animal	Number Exposed	Number Recovered Alive	Number Having Died since Re-turning to the BURLESON	Number Killed for Study	Number Alive on 25 Nov 46
Goats	176	153	26	12	115
Pigs	147	136	32	18	86
Rats	3130	2511	725	321	1465
Guinea Pigs	57	55	55	0	0
Mice	109	108	*	*	*

* Mice were exposed at considerable distances from the Zeropoint in order to provide data as to results of exposure to sub-lethal dosages of gamma radiation.

15.003 Dependence of Mortality on Range.

Presented below are the JTF-1 Technical Historian's estimates of mortality percentages:

Type of Animal	Range (yd)	Percentage of Animals of Indicated Type Which Had Died by 9 Aug 46 as a Direct Result of Blast and Radiation
Pigs	Less than 1000	50 ± 10
	1000 to 2000	15 ± 5
	More than 2000	15 ± 10
Goats	Less than 1000	85 ± 10
	1000 to 2000	30 ± 25
	More than 2000	5 ± 5
Rats	Less than 1000	75 ± 10
	1000 to 2000	25 ± 10
	More than 2000	15 ± 5

The significance of these figures is reduced by the fact that no account is taken of different distributions of the animals throughout their respective ships, or of different sample sizes; no analyses taking into account these factors were available by 15 Nov 46.

15.004 Relationship Between Mortality and Type of Animal.

No reliable conclusion can be drawn from the figures of the preceding section as to relative vulnerabilities of goats, pigs, and rats. However, long-range mortality figures (for period ending 5 Nov 46) indicate that pigs may be slightly more vulnerable to gamma radiation than goats or rats.

15.005 Degree of Protection of Animals.

As of 15 Nov 46 no shield-thickness data were available for the various animals exposed. Note: Lethal dosage of gamma radiation is usually taken to be 400 roentgens; lethal dosage of fast neutrons is 1×10^{11} fast neutrons per cm^2; for slow neutrons, the lethal dosage is 5×10^{11} slow neutrons per cm^2. Flash burn in animals at ranges greater than 600 yd was prevented by flash-burn cream or by fur.

15.006 Symptoms of Injury.

A. Symptoms Produced by Gamma Radiation. Animals receiving light doses of gamma radiation often appeared normal. Later some developed hemorrhagic patches beneath the oral mucous membrane. A few showed partial loss of hair and very few developed testicular atrophy.

Those animals more heavily exposed exhibited hyperirritability, muscular weakness, diarrhea, and increased rate of respiration. Some of these were moribund, with exaggeration of symptoms, bloody diarrhea and inability to stand.

B. Symptoms Produced by Air Blast. Symptoms of blast injury were: lung hemorrhages and contusions.

15.007 Radiological Dosage.

Since radiological dosage data are considered in detail in Chap. 17, only a summary of the most salient data are presented here.

At horizontal ranges of 0 to 1000 yd, topside dosage of gamma radiation was 1800 to over 8000 roentgens; inside heaviest turrets and below decks in very well-protected regions, the typical dosage was 1 to 50 roentgens. Neutron dosages were very high (lethal, ordinarily) within 500 yd, but were almost negligible beyond 700 yd. (Source: Ref. 300-20.)

Between 1000 and 2000 yd, topside dosage of gamma radiation varied from 28 to 1800 roentgens, while the dosage in well-protected regions was from 0 to 20 roentgens. The neutron dosage in this range was practically nonexistent.

Beyond 2000 yd, topside dosage of gamma radiation varied from 28 roentgens to zero; the dosage in well-protected regions was less than 1 roentgen.

15.008 Causes of Injury.

Air blast was the principal cause of injury leading to immediate (i.e., within the first hour) deaths and other immediate "loss of efficiency" of exposed animals; gamma radiation was second in importance. (Many of the animals killed by the air blast received lethal dosages of gamma radiation.)

Neutron radiation would have been important in protected locations at ranges less than 650 yd, had there been any animals at such range.

Principal cause of delayed deaths and delayed "loss of efficiency" was gamma radiation.

15.009 Ranges of Injury of Specified Severity.

No estimate is included here as to the range at which it is probable (probability greater than 50 percent) that animals would be injured to a specified extent, since for various reasons any such estimates would be both inaccurate and of questionable significance. (See, however, Chap. 19, where estimates of ranges for probable injury to crews are presented.)

Chapter 16

Pressure Data, Test A

Outline

Chapter 16

Pressure Data, Test A

16.001 Introduction.

Detailed accounts of pressure produced by Bomb A are contained in Ref. 300, particularly Ref. 300-13.

16.002 Peak Pressure in Mach Stem Region.

Best values of peak pressure in the Mach Stem region, the air just above the surface of the water, are given below. (Source: Ref. 300-13, Fig. 2, curve "BuOrd")

Horizontal Distance from Projected Zeropoint (yd)	Peak Pressure (psi gage)
0	2000
360	110
400	87
500	53
600	36
700	25
800	18
900	13.5
1000	10.5
1100	8.7
1200	7.3
1300	6.2
1400	5.4
1500	4.8
1600	4.3
1700	4.0
1800	3.7
1900	3.3
2000	3.1
2500	2.3

According to Dr. W. G. Penney (Ref. 300-13), all best values (except those for distances less than 100 yd) have probable errors in the neighborhood of 5 percent. But according to JTF-1 Technical Historian, the data of Ref. 300-13 show that the best values ordinarily have probable errors of 10 to 20 percent, and values for distances less than 500 yd may have probable errors of 30 percent or more.

16.003 Peak Pressure Outside Mach Stem.

Peak-pressures values obtained at positions outside the Mach Stem region are given below: (Source: Ref. 300-22)

Altitude (ft)	Slant Range (yd)	Peak Pressure (psi gage)
26,800	11,100	0.168
26,800	11,800	0.178
26,800	13,300	0.150

By 1 Nov 46 no estimate of probable error had been made.

A peak pressure of 100 dynes/cm was measured at Kwajalein, approximately 218 nautical mi away. (Source: Ref. 300-19)

16.004 Duration of Positive Pressure Pulse at a Fixed Point in Air.

Duration of the positive pressure pulse at a fixed point in the Mach Stem region, just above the surface of the water, was as follows: (Source: Ref. 300-13)

Horizontal Distance from Projected Zeropoint (yd)	Duration of the Positive Pressure Pulse (sec)
360	0.42
500	0.46
750	0.59
1000	0.75
2000	1.0

By 1 Nov 46 no estimate of probable error had been made.

16.005 Shape of Pressure versus Time Curve (in Air).

The shape of the pressure versus time curve (at a fixed point in air in Mach Stem region) at various radii (exceeding 750 yd) obeyed the following equation: (Source: Ref. 300-13)

$$p(t) = P\left(1-\frac{t}{T_o}\right)e^{-t/T_o} \qquad \text{(Eq.1)}$$

Where P is the initial shock-wave pressure (psi) at the fixed point concerned, t is the time in seconds at which the pressure p(t) is desired, and T_o is the duration of the positive pressure pulse, evaluated in the preceding section. The shape is pictured in Ref. 300-13, Fig. 4.

For points less than 750 yd horizontal distance from the projected Zeropoint, the equation is of limited value, although it may still be applicable to the positive pressure pulse.

16.006 Velocity of the Shock Wave in Air.

No "best value" data were available in the office of the Technical Director on 1 Nov 46 as to the velocity of the shock wave in air.

Dr. R. M. Frye of Task Unit 1.5.2 presents (Ref. 510-1, Fig. II-B-1) the following preliminary (motion-picture film) data for the rate of propagation of the shock wave in air:

(1) Time after Mike Hour (sec)	(2) Horizontal distance from Projected Zero-point of intersection of shock-wave-in-air with the surface of the water (ft)	(3) Slant Range from Actual in-the-air Zeropoint to surface of water (ft)	(4) Slant-range-velocity, or rate of increase of the slant range as defined in Column (3) (ft/sec)
0.0	0	0	14,200
0.2	1020	1260	3,000
0.4	1600	1740	2,200
0.6	2000	2110	2,000
0.8	2380	2480	1,830
1.0	2700	2790	1,750
1.5	3530	3595	1,590
2.0	4350	4400	1,470

By 1 Nov 46 no estimate of probable error had been made. JTF-1 Technical Historian estimates the probable error to be in the neighborhood of 5 percent for data applicable to times more than 0.2 seconds after MIKE Hour.

An equation relating peak pressure P and shock-wave velocity U is given below. It is applicable in the region where the peak pressure in air was less than 500 psi, that is, at horizontal distances from the projected Zeropoint greater than 300 yd. (Source: Ref. 300-13)

$$P = \frac{7}{6} P_o \left[\left(\frac{U}{a}\right)^2 - 1 \right] \qquad \text{(Eq.2)}$$

Here P_o is the ambient atmospheric pressure (1012.2 millibars at sea level at MIKE Hour) and a is the ambient velocity of sound (1140 ft/sec at sea level at MIKE Hour). By 1 Nov 46 no estimate of probable error had been made.

16.007 Time of Arrival of Shock Wave in Air.

At distances greater than 5 mi the time of arrival of the shock wave in air was identical to that of an acoustical signal of low intensity, starting from a point 1665 ft nearer to the observer than is the actual detonation point. (Source: Ref 300-22)

The shock wave reached the surface of the water 56 milliseconds after MIKE Hour. (Source: Ref. 510-1)

16.008 Sound Produced.

The sound of the detonation was heard as a rather faint low rumble by persons 20 mi away on surface vessels.

16.009 Pressure within Target Vessels.

Peak pressures of 2.5 to 5 psi gage were reached in the (purposely-left-open) BRULE, situated 1005 yd from the projected Zeropoint. Peak pressure in closed ships never exceeded 2.5 psi gage. (Source: Ref. 300-13)

Chapter 17

Radiation and Radioactivity, Test A

Outline

Chapter 17

Radiation and Radioactivity, Test A

17.001 Introduction.

This Chapter discusses only radiations and radioactivity in Test A. Their effects are considered in other chapters.

17.002 Optical Radiation.

A. Total Emission. No meaningful value was obtained for the total quantity of energy emitted by the detonation as optical radiation. A value was obtained but it was absurdly high, being equal to twice the total amount of energy actually emitted by the detonation. (Source: Ref. 300-18; 300-7)

B. Spectral Distribution at Short Distance. No data were available by 1 Nov 46 as to the spectral distribution of the optical radiation at a specified short distance from the detonation point. At an unspecified (short) distance, and in a short range above 6000 A and in a short range below 4000 A (but not in the range from 4000 to 6000 A) the time-integrated intensity was inversely proportional to the fourth power of the wavelength. (Source: Ref. 300-18)

C. Flux at 18 Nautical Miles. At 18 nautical mi, on a surface vessel or on an airplane, the actually-received, time-integrated flux of optical radiation throughout the spectrum was 5×10^5 ergs/cm^2. (Source: Ref. 300-18) By 1 Nov 46 no estimate of probable error had been made.

D. Flux on Target Vessels. By 1 Nov 46 analysis of the data was not sufficiently advanced to give the time-integrated flux of optical radiation on target vessels.

E. Illumination at 12 Nautical Miles. At 12 nautical mi the peak illumination was approximately 100,000 ft-candles, which is roughly 10 times greater than is produced by noon summer sun and skylight. (Source: Ref. 510-1)

F. Spectral Distribution at Long Range. At 18 nautical mi, no optical radiation of wavelength less than 3200 A was received. The wavelength of greatest intensity was 7000 A. The shorter the wavelength, the less was the intensity. This diminution in intensity was more pronounced than in the spectrum of the (noon) sun. Various atmospheric absorption lines appeared in the apectrograms. (Source: Ref. 300-18)

G. Time Distribution. There were no data for which the distribution of optical radiation can be computed as a function of time.

However, it is known that by the end of the first millisecond after Mike Hour only 7 percent of the total cumulative amount of 3600 A radiation to be received at 18 nautical mi had been received, and only 2 percent of the total cumulative amount of 9400 A radiation to be received had been received. (Source: Ref. 300-18)

Dr. R. M. Frye of Army Air Unit 1.5.2 reports that the total illumination at distant points passed through two maxima: principal maximum occurred at 0.1 milliseconds and the secondary maximum occurred at 120 milliseconds. (Source: Ref. 510-1)

17.003 Fireball.

The fireball was formed in the detonation itself. Its radius grew as follows:

Time after Mike Hour (sec)	Radius (ft)
10^{-5}	10
10^{-4}	40
10^{-3}	110
10^{-2}	260
10^{-1}	520
1	800
10	870

By 1 Nov 46 no estimate of probable error had been made.

The fireball ceased to exist as such at approximately 10 sec after Mike Hour. What had been the fireball became the mushroom top.

During the early growth the radius roughly obeyed this relationship:

$$R = 1678.\ T^{0.4} \qquad \text{(Eq. 1)}$$

Growth of the fireball to a radius of about 40 ft was by radiative transfer process; thereafter, growth was by mechanical or hydrodynamical process rather than by radiative process. (Source: Ref. 300-22)

The greatest surface temperature of the fireball was reached at 150 microseconds after Mike Hour, and the temperature value was in the neighborhood of 200,000° K. (Source: Ref. 300-22, Fig. 2) By 1 Nov 46 no estimate of the probable error had been made.

To observers 12 nautical mi away, the illumination produced per cm^2 of the fireball area was, at the instant of greatest brightness, several times that of the sun at noon; the color temperature of the fireball was considerably higher. (Source: Ref. 510-1)

17.004 Gamma Radiation.

A. Emission from the Detonating Bomb. No information is available as to total quantity of gamma radiation produced in the detonation. Much of the radiation was absorbed by the bomb materials themselves during the detonation process: much was absorbed by the air before reaching the Lagoon surface or target vessels; much was emitted after the great bulk of the fission products had been carried to higher altitudes.

The average energy emitted (per fission) as gamma radiation was 1.8 Mev. Approximately 40 percent of the energy represented by gamma radiation was (at the time the radiation was emitted) in the form of quanta of 5 Mev. (Source: Refs. 300-22, 300-20)

B. Time Incidence on Target Vessels. Forty five percent of the gamma radiation reaching the target vessels reached them by one sec after Mike Hour; 80 percent had reached them by 3 sec after Mike Hour; 99 percent had reached them by 10 sec after Mike Hour.

The great majority of the gamma radiation incident on target vessels came from the detonating bomb and from the fission products. It is estimated that less than 1 percent of the gamma radiation was from neutron capture in the non-fishant bomb materials. (Source: Ref. 300-22)

C. Total Quantity Reaching Specified Radius at the Surface of the Lagoon. The total cumulative amount of gamma radiation from the detonation proper (and from the fission products) reaching a specified point just above the surface of the water was as indicated below: (Source: Ref. 300-22, Fig. 5)

Horizontal Distance from Projected Zero-point. (yd)	Cumulative Gamma Radiation as defined above. (roentgens)
600	9000
700	6000
800	4000
900	2600
1000	1800
1100	1200
1200	770
1300	500
1400	330
1500	220
1600	150
1800	63
2000	28

The JTF-1 Technical Historian estimates that the probable error of these data is 15 percent.

These data conform to the following equation:

$$\text{No. of roentgens} = \frac{2.9 \times 10^{10} \times 10^{-R/845}}{R^2} \qquad \text{(Eq. 2)}$$

Where R is the (horizontal or slant) distance in yd. (Source: Ref. 303)

D. Atmospheric Attenuation Constant. At the instant of emission of the gamma radiation by the detonation proper the atmospheric attenuation constant was 340 meters (370 yd). That is, atmospheric absorption alone tended to reduce the radiation to 1/e (or 37 percent) of its initial value in traversing 340 meters of air at sea level. (Source: Refs. 300-20; also 300-22)

E. Induced Gamma Radiation. The total amount of induced gamma radiation in the Lagoon water, at 4 hr after Mike Hour was 0.5 roentgens per 24 hr in a central area of approximately 1 mi^2. This induced radiation resulted almost entirely from the formation of sodium 24 (half-life 14.8 hr) by neutron capture.

Induced gamma activity on target vessels which remained afloat was in general less than in the water. Materials rendered particularly radioactive were soap, salt, glass (which contained sodium) and arsenicals, brass, and a few other special items. (Source: Ref. 303)

17.005 Neutron Radiation.

The time-integrated flux of slow neutrons from the explosion varied with distance in approximate accordance with Eq.(3): (Source: Ref. 300-22)

$$\frac{\text{No. of slow neutrons}}{\text{cm}^2} = 2.24 \times 10^{12} \times 10^{-(R/550)^2}, \quad \text{(Eq. 3)}$$

where R is the slant range in meters.

The time-integrated flux of fast neutrons from the explosion varied with distance as indicated by the following table: (Source: Ref. 300-20)

Slant Range (yd)	Time-Integrated Flux of fast neutron per unit area at the indicated slant range (neutrons per cm^2)
400	1×10^{11}
600	1.6×10^{10}
800	3.3×10^{9}
1000	8×10^{8}

The atmospheric attenuation constant of fast neutrons was (at slant range greater than 800 yd) 160 yd. That is, scattering by the atmosphere over a path length of 160 yd reduced the flux of fast neutrons to 1/e (or 37 percent) of its initial value. At shorter ranges, the attenuation with distance was less. (Source: Ref. 300-22)

Neutrons reaching the water produced radioactive sodium 24, which has a half-life of 14.8 hr. Neutrons were absorbed also by hydrogen and chlorine in the water, by sodium, zinc, and arsenic in target vessels, and of cource, by nitrogen in the air. (Source: Ref. 300-20)

17.006 Alpha Radiation.

Very little alpha radiation was present at the surface of the Lagoon: its effect was negligible.

17.007 Beta Radiation.

Although considerable beta radiation was produced in the immediate neighborhood of the detonation, very little such radiation was present at the surface of the Lagoon. Its effect was negligible.

17.008 Gamma and Neutron-Radiation Dosages in Target Vessels.

Gamma-radiation dosages on the most exposed topside parts of target vessels were, of course, substantially as indicated in Sec. 17.004.

Gamma-radiation dosages on topside regions shielded by superstructures and in interior compartments were usually far less, typically by a factor of 10 to 100. (Source: Ref. 300-20)

(Dosages on submerged submarines would presumably have been negligible. However, no submarines were submerged during Test A.)

Neutron-radiation dosages on the most exposed topside parts of target vessels were, of course, substantially as indicated in Sec. 17.005. Dosages in "shielded" regions of the vessels were not greatly reduced, since neutrons are not greatly absorbed by steel or other materials common in vessels.

17.009 Residual Radioactivity on Target Vessels.

The residual radioactivity, i.e., radioactivity present after one minute after Mike Hour, on target vessels was low. Residual radioactivity on A-Day itself was not determined. One day after A-Day radioactivities greater than 0.1 roentgens per 24 hr were found on only 13 vessels. (Source: Ref. 300-20)

One day after A-Day the three most radioactive (not-immediately-sunk) vessels were SKATE, ARKANSAS, and SAKAWA. (Source: Ref. 300-20) The maximum radioactivity measured on any surviving ship was at that time approximately 8 roentgens per 24 hr. This value was found for a pool of water on the ARKANSAS. (Source: Ref. 303)

17.010 Residual Radioactivity in the Water.

The residual radioactivity in the water after Mike Hour was negligible and of no physiological significance. Thus at 4 hr after Mike Hour in an 0.8 mi^2 area roughly centered at the projected Zero-point, the intensity was only 0.5 roentgens per 24 hr. By 30 hr after Mike Hour the figure had decreased to 0.1 roentgens per 24 hr. (Source: Ref. 300-20)

Principal cause of the radioactivity in water was neutron-produced radioactive sodium 24, of 14.8-hr half-life. (Source: Ref. 300-20) This sodium isotope emits beta particles and gamma rays.

17.011 Residual Radioactivity in Air.

There was appreciable residual radioactivity in the air about 70 mi to leeward 13 to 17 hr after Mike Hour, and detectable radioactivity in the air roughly 4000 mi away (Puget Sound Area) 150 hr after Mike Hour. (Source: Ref. 300-20 and Ref. 300-19)

This radioactivity originated, of course, in the fission products dispersed in the air.

Chapter 18

Other Detailed Results of Test A

Outline

Chapter 18

Other Detailed Results of Test A

18.001 The Cloud.

By 20 sec after Mike Hour the cloud had assumed its characteristic mushroom shape and was one mile high. By 150 sec after Mike Hour it had reached an altitude of nearly 5 mi; its maximum width was 9000 ft, and a thin cap, presumed by some to be an ice cap, had formed. By 400 sec after Mike Hour the cloud had reached an altitude of 7 mi. (Source: Ref. 510-1)

Practically all the fission products produced in the detonation rose in the cloud; they were detected several days later at great distance, as explained in a following section.

18.002 Water Waves.

Water waves produced in the Test were of negligible significance. At the projected Zeropoint the surface of the water was first depressed by approximately 6 ft; the depression lasted for approximately 8 sec. The depression was followed by a rapid rise to a height of 2 ft above the normal level, after which the surface returned to normal level. (Source: Ref. 300-16)

18.003 Other Results.

A. Radioactivity at Great Distance. Radioactivity from the explosion was definitely detected at many remote sites. At the Puget Sound Naval Shipyard, for example, the counting rate near the surface of the earth increased by 35 percent approximately 150 hr after Mike Hour. (Source: Ref. 300-19)

B. Reflectivity and Conductivity Phenomena. No atmospheric reflectivity or conductivity phenomena were detected at great distances. Even locally no noteworthy effects were found.

C. Seismological Phenomena. No earth shock was detected at appreciable distance.

D. Magnetic Phenomena. No magnetic phenomena were detected.

E. Ionization Phenomena. No significant ionization phenomena were detected.

F. Remote Detection. Remote detection was accomplished only by radioactivity in the air. See the foregoing Paragraph A.

Chapter 19

Correlation and Discussion of Test A

Outline

Section

Chapter 19

Correlation and Discussion of Test A

19.001 Introduction.

This Chapter contains, first, general correlations and conclusions regarding the outcome of Test A, and second, various comments on the adequacy and success of the Test from a technical and technical-administrative point of view.

The correlations and conclusions are for the most part those of the JTF-1 Technical Historian. Most of them have not been approved, and it is expected that further study by experts will lead to minor changes in the correlations and conclusions. The tentative findings presented here are intended (1) to give a rough over-all picture of the outcome of the Test, and (2) to serve as a basis of discussion.

19.002 Loss of Military Efficiency of Ships.

A. Introduction. A rough but simple definition of military efficiency of a ship itself is included in Appendix III.

B. Immediate Loss. Fig. 19.1 shows the range (estimated by the JTF-1 Technical Historian) at which specified extent of immediate (i.e., first hour) loss of military efficiency of "typical" surface combatant vessels themselves is probable (probability equal to 50 percent). Ranges are horizontal distances from the projected Zeropoint. Estimates apply to U. S. surface combatant vessel of unspecified type.

The pertinent data are:

Range for very serious immediate loss:	900 yd
Range for serious immediate loss:	1000 yd
Range for moderate immediate loss:	1300 yd
Range for slight immediate loss:	1500 yd

C. Long Term Loss. It is not possible to make useful estimates as to the long term loss of military efficiency of ships themselves. Even serious loss of military efficiency of a ship itself may be corrected in hours or days in some cases, especially if the ship is very close to a repair yard; yet even small loss of military efficiency of the ship itself may take months to correct, if the damage is deep-seated and if the ship is far from base.

D. Weakest Link. At ranges greater than 700 yd the weakest links as regards loss of military efficiency of ships themselves are: stacks and boilers (most important), and antennas. Within 700 yd hulls and ordnance equipment become weak links also.

19.003 Loss of Military Efficiency of Crews.

A. Introduction. A rough but simple definition of efficiency of a crew per se is included in Appendix III.

B. Immediate Loss. Fig. 19.1 shows the range (estimated by the JTF-1 Technical Historian) at which specified extent of immediate (i.e., first hour) loss of military efficiency of crews per se would be probable (probability equal to 50 percent). (Normal 1945 shielding is assumed; also "typical" type and orientation of ship.) The ranges of principal interest are:

Range for very serious immediate loss of efficiency	700 yd
Range for serious immediate loss of efficiency	800 yd
Range for moderate immediate loss of efficiency	900 yd
Range for slight immediate loss of efficiency	1000 yd

C. Long Term Loss. Principal ranges for long term loss (of indicated severity) of military efficiency of crews per se are:

Range for very serious long term loss	800 yd
Range for serious long term loss	1100 yd
Range for moderate long term loss	1400 yd
Range for slight long term loss	1700 yd

However, the significance of these figures is questionable since it would often be possible to replace the crew within a few weeks.

D. Weakest Link. It appears that, at virtually all horizontal ranges of interest, the type of injury producing greatest immediate loss of military efficiency to crews would be injury from air blast, including primary effects, secondary effects (injury from impact with flying debris, ship structures, etc.) and general confusion created. Next in importance would be burns, injury to lungs and eardrums, and injury to bone marrow and white blood corpuscles.

19.004 Loss of Combined Military Efficiency.

A. Introduction. For simplicity, the abbreviation CME is used below for "combined military efficiency." A rough but simple definition of combined military efficiency is included in Appendix III. The term refers, of course, to the efficiency of ship and ship's crew con-

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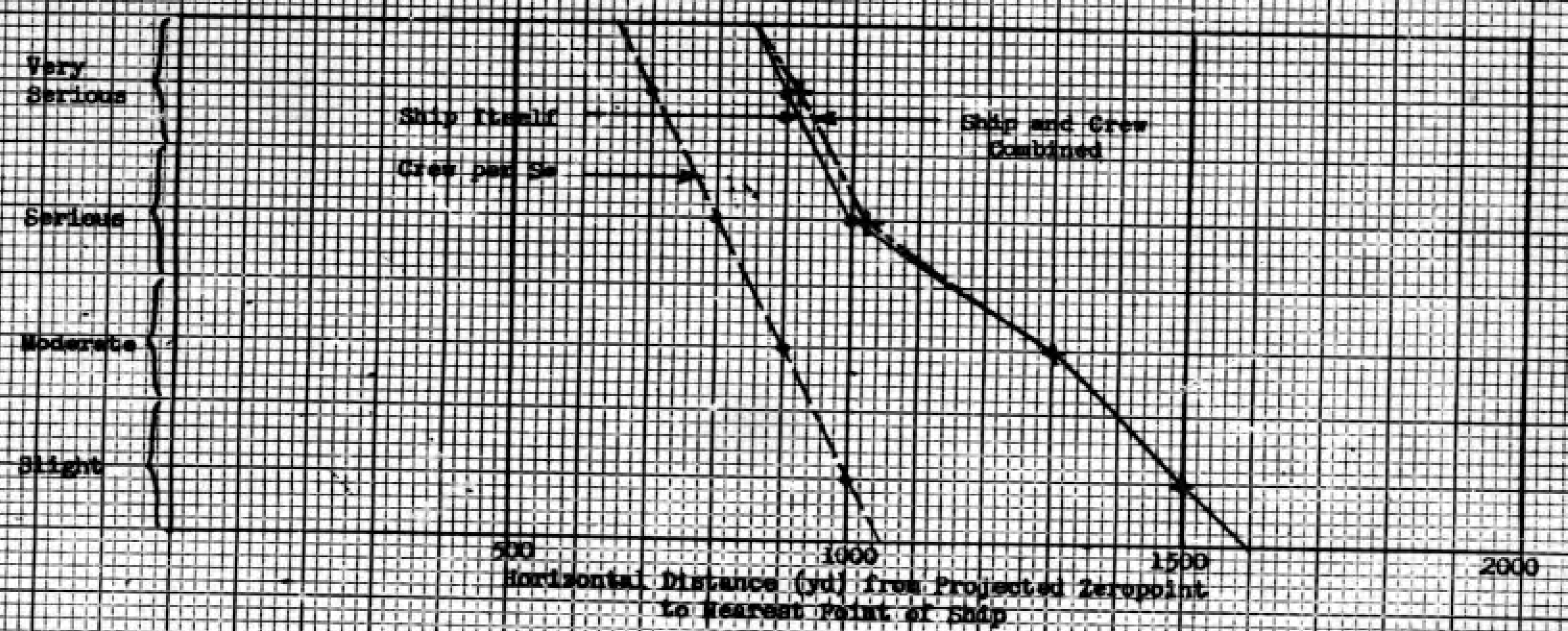

Fig. 19.1 Immediate Loss of Military Efficiency Versus Range, Test A

Source: Estimates by JTF-1 Technical Historian

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sidered in combination.

B. Immediate Loss. Figure 19.1 shows the range (estimated by the JTF-1 Technical Historian) at which specified extent of immediate (i.e., first hour) loss of combined military efficiency would be probable (probability equal to 50 percent).

The most interesting ranges are:

Range for very serious immediate loss of CME	900 yd
Range for serious immediate loss of CME	1020 yd
Range for moderate immediate loss of CME	1300 yd
Range for slight immediate loss of CME	1500 yd

C. Long Term Loss. For reasons indicated in the preceding sections, it is impossible to make any meaningful estimate of long term losses of combined military efficiency.

D. Weakest Link. The weakest link, as regards immediate loss of combined military efficiency, is the ship itself, especially stacks, boilers, antennas and (within 700 yd) hulls and ordnance equipment.

19.005 Decreasing the Ranges of Loss of Military Efficiency of the Ships Themselves.

Considerable reduction in the ranges at which the ships themselves suffer specified losses of military efficiency could be achieved by improving the resistance of stacks and masts (masts supporting antennas).

Such improvements might reduce the ranges of serious and very serious immediate loss of military efficiency by approximately 100 yd.

19.006 Decreasing the Ranges of Loss of Military Efficiency of the Crews Per Se.

Considerable reduction in the ranges at which the crews would suffer specified immediate losses of military efficiency could be achieved by placing all personnel inside ships or by providing topside personnel with protection against the pressure wave in air. (Care would have to be taken to see that the screens themselves could not become missiles.)

Providing steel screens to reduce the intensity of gamma radiation would not be of appreciable value as far as efficiency during the first hour is concerned, except perhaps at short range; and even here the value would be small because the ships would ordinarily be out of the battle.

19.007 Decreasing the Ranges of Loss of Combined Military Efficiency.

Since, during the first hour after an air burst, damage to ships is the all-important consideration as far as immediate military efficiency is concerned, reducing the ranges of ship vulnerability is the obvious immediate goal. (See Sec. 19.005.)

19.008 Ranges of Damage or Injury Produced by Causative Factors.

A. Introduction. No formal analysis has been made as to what causative factors are predominant at various specified ranges; however, the following estimates by the JTF-1 Technical Historian may be of value:

B. Shock Wave in Air. Shock wave in air is the cause of greatest immediate loss of military efficiency of ships.

A typical surface vessel will probably be sunk by a pressure wave in air having a peak pressure greater than 35 psi gage; it will probably suffer very serious immediate loss of military efficiency when subjected to a peak pressure greater than 25 psi gage; peak pressures of 20, 15, and 10 psi gage will probably produce serious, moderate, and slight immediate losses of military efficiency, respectively.

Shock wave in air (including primary and secondary effects) is comparable to optical radiation as a cause of immediate loss of military efficiency of crews at ranges greater than 900 yd. Peak pressure of 10 to 100 psi gage might be required to produce death as a primary effect; peak pressures as low as 5 psi gage might cause death from secondary effects of impact with ship structures.

C. Gamma Radiation. Gamma radiation would contribute very little to the immediate loss of combined military efficiency. It would be of slight importance at ranges less than 1000 yd, and of negligible importance at greater ranges.

Gamma radiation would probably be the greatest cause of long-term loss of military efficiency of crews on ships within 1500 yd, since (unlike the shock wave in air) it would produce serious injury even to persons protected by thin and moderately thin layers of steel; that is, it would affect personnel below decks in addition to affecting topside personnel. Exposed persons at range of 1350 to 2000 yd might die from exposure to gamma radiation, but the probability would be less than 50 percent. Exposed persons within 1350 yd would probably die from exposure to gamma radiation. Best protected persons as close as 600 yd might not receive lethal gamma radiation doses.

A gamma radiation dose of 400 roentgens would probably be fatal to man. After exposure to such a dose, nausea sets in within 30 to 60 min; weakness develops gradually after the first day, and mortality probably would result within one month.

A gamma radiation dose of over 2000 roentgens would produce nausea within approximately 30 minutes and weakness might often develop within 60 min; death would occur within 36 hr.

Gamma radiation intensity is reduced to 50 percent by a 2-cm thickness of steel, and to approximately 1 percent by 14 cm (5½ in.) of steel. Thus 2 cm. of steel would reduce the lethal radius from 1350 yd to 1200 yd, and 14 cm of steel would reduce the lethal radius to less than 600 yd. (However, neutron radiation would become very serious at ranges of less than 650 yd, and would not be adequately stopped by 14 cm of steel, as explained below.)

D. Neutron Radiation. Neutron radiation would contribute virtually nothing to the immediate loss of combined military efficiency.

Neutron radiation would contribute virtually nothing to the long-term loss of military efficiency of crews outside 700 yd.

Neutron radiation would be the greatest cause of injury to personnel in "very well protected" regions on ships within the annulus extending from 550 to 650 yd. In this annulus even 15 cm of steel would afford little protection.

Since it is probable that a surface combatant ship of unspecified type situated within 550 yd sinks, it is probable that neutron radiation is of reduced military importance within that range.

The neutrons which are present in the 550 to 650-yd annulus are slow neutrons; fast neutrons are almost non-existent beyond 550 yd.

E. Other Causative Factors. Optical radiation (heat flash) would rival shock wave in air as principal cause of immediate loss of military efficiency of crews at ranges greater than 900 yd. It would produce serious (second degree) burns on exposed skin at ranges as great as roughly 1700 yd.

Beta radioactivity, alpha radioactivity, and induced radioactivity were not important.

Unfished fissionable materials were not present (i.e., at sea lewel) in significant quantities.

Importance of psychological effects (as on persons who might know they would soon die from effects of gamma radiation) was not investigated.

F. Comparison of the Effectiveness of the Various Causative Factors. Air blast (including primary and secondary effects, and the general confusion created) would be the most important cause of immediate loss of combined military efficiency. This is true for all ranges.

The same statement applies to immediate loss of military efficiency of ships.

Within 650 yd, principal cause of immediate loss of military efficiency of crews would be neutron radiation; in the annulus from 650 to 900 yd the principal cause would be gamma radiation; outside 900 yd shock wave in air and optical radiation would be collectively the principal cause.

19.009 Technical Shortcomings of the Test.

Although the Test was in the main almost completely successful, several shortcomings deserve mention.

A. The Bomb Miss. The plan-view position of the bomb at the instant of detonation was 710 yd from the intended projected Zeropoint -- foremast of NEVADA -- and at 281° True. The projected actual Zeropoint was 700 yd west and 136 yd north of the intended projected Zeropoint. (Note that the slant range was not between 1500 and 2000 ft, as originally announced, but was 2130 ft.)

The cause of the miss had not been determined by 15 Nov 46, and it is likely that the cause will never be discovered. Extensive studies have been made by several groups, but neither separately nor collectively do the findings explain the miss. There is strong evidence that the bombing plane was at approximately the correct altitude, that the bombsight was in proper condition and adjustment, that the ballistic wind correction was appropriate, and that the bomb was released at the correct instant and started its descent in normal manner. (The time of fall was 48.1 ± 0.3 sec, which was 0.5 sec longer than predicted; such a deviation is suggestive of a slightly rough flight but is inconsistent with a bad wobble or a spiral flight.) There is also weighty evidence that the bomb itself was of very sound and strong aerodynamic design and should not have wobbled or drifted. Data available on 1 Nov 46 ascribe to the bombing plane a position and course (at the instant of bomb release) such as to place the bomb 600 ft to the left of the intended Zeropoint and at least 1000 ft over, which by no means corresponds with the actual detonation point. Since there is at present no tenable hypothesis as to why the miss occurred, the matter will not be discussed here.

It is well known that the miss prevented the optimum functioning of many of the instruments, prevented conclusive demonstration as to whether an air burst can sink a battleship, and had other deleterious consequences.

B. Timing-Signal Failure. Two individual errors produced the timing-signal failure, as a result of which a considerable number of instruments were started late and thus failed to obtain the desired data. First, the timing control operator made a premature decision that the expected tone break (in the signal transmitted from the bombing plane) had occurred; he then (prematurely) started the automatic timers controlling the timing signals; and when he found that the tone break had not occurred, he had to abandon the automatic timers. Second, after switching to manual keying, the timing control operator read the time from the wrong clock — one which was based on the minus-2-min mark as given by the bombardier and not expected to be highly accurate.

C. Black-Box Failures. A small but appreciable fraction of the "black-box" instrument-starting devices failed to operate successfully, with the result that the corresponding instruments failed to obtain the desired data. In some instances the black-box failures were merely the result of lack of time to carry out adequate tests; in some instances the boxes were affected by the high (radio) noise level in the target array area, the noise level being especially high just at How Hour. In some instances the black-box failures were partly a result of administrative division of responsibility, one group being responsible for the boxes themselves and a different group being responsible for the apparatus into which the black-box signal was fed.

D. Excessive Density of Goggles. The goggles distributed among important technical and observer personnel were unnecessarily dense.

19.010 General Appraisal of the Test.

From the technical point of view as well as from the operational point of view the Test was very successful. Graded damage was produced in ships of many types; graded injury was produced in animals of several types; and the principal physical phenomena (causative factors) were evaluated with reasonably good accuracy. A firm basis was established for determining the vulnerability of ships and crews to air bursts of atomic bombs, and for improving future designs and tactics.

Shortcomings there were. But they were few in number, noncrucial in character, and, in view of the shortage of time and technical personnel and the unique character of the problems presented, it is difficult to see how they could have been avoided.

Chapter 20

Execution of Test B

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Chapter 20

Execution of Test B

20.001 Introduction.

Whereas Bomb A was detonated in the air while falling freely, Bomb B was detonated while at rest beneath the surface of the water.

20.002 Delivery of Bomb.

The Bomb was delivered to LSM-60 by means outside the scope of this report. See Chap. 5 for a description of the final positioning beneath LSM-60.

20.003 Detonation of Bomb.

The bomb was detonated (by means described in Chap. 5) at 59.7 sec after 0834 on 25 July 46, Bikini Local Time. This corresponded to 1634:59.7 on 24 July (EST) and 2134:59.7 on 24 July (GCT). Final firing signals were sent out from the CUMBERLAND SOUND.

At the instant of detonation, the location of the bomb was as follows:

Depth below Lagoon surface: 90 ft.

Latitude: 11° 35' 05" N.

Longitude: 165° 30' 30" E.

20.004 Status of Actual Array of Target Vessels.

Table 20.1 shows the B-Day, Mike Hour positions and aspects of the target vessels.

Table 20.2 shows the conditions of target vessels within 1000 yd of Zeropoint as regards fuel and ammunition loads.

TABLE 20.1. RELATIVE POSITIONS OF TARGET VESSELS ON B-DAY AT MIKE HOUR.
Note: All distances are horizontal distances from actual projected Zeropoint.

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Vessel	Range fm Burst to Bow (Yd)	True Bearing of Bow from Burst		Relative Bearing of Burst from Bow		Coordinates of Vessel from Burst (Yd)				Distance from Burst to Nearest Part of Vessel (Yd)	Direction of Burst from Vessel
						Bow		Stern			
		deg	min	deg	min	X	Y	X	Y		
Battleships & Cruisers											
Arkansas, BB 33, 562*	259	10	26	107	16	47 E	255 N	138 W	232 N	223	Stbd. Beam
New York, BB 34, 573	1007	109	54	183	10	943 E	341 S	763 E	288 S	820	Stern
Nevada, BB 36, 583	1056	8	53	94	16	163 E	1042 N	29 W	1057 N	1030	Stbd. Beam
Pennsylvania, BB 38, 608	1283	174	46	156	19	117 E	1278 S	182 E	1085 S	1104	Stbd. Qtr.
Pensacola, CA 24, 586	640	270	27	356	41	641 W	5 N	836 W	15 N	640	Bow
Salt Lake City, CA 25, 586	1256	61	57	134	37	1108 E	590 N	923 E	650 N	1120	Stbd. Qtr.
Nagato, JAP BB,	852	29	52	122	0	424 E	739 N	178 E	730 N	745	Stbd. Qtr.
Sakawa, JAP CL,	Sunk during Test A										
Prinz Eugen, IX 300,	1990	298	48	309	08	1744 W	959 N	1767 W	1169 N	1990	Port Bow
Aircraft Carriers											
Saratoga, CV 3, 910	446	208	03	124	10	210 W	395 S	93 E	360 S	350	Stbd. Beam
Independence, CVL 22, 619	1436	245	54	259	24	1311 W	587 S	1361 W	383 S	1390	Port Beam
Destroyers											
Lamson, DD 367, 344	Sunk during Test A										
Conyngham, DD 371, 344	3597	295	03	308	51	3259 W	1523 N	3286 W	1640 N	3597	Port Bow
Mugford, DD 389, 341	2595	309	04	314	30	2015 W	1636 N	2028 W	1752 N	2595	Port Bow
Talbot, DD 390, 341	1835	249	23	263	12	1719 W	647 S	1746 W	533 S	1815	Port Beam
Mayrant, DD 402, 341	813	338	33	352	18	297 W	757 N	324 W	870 N	813	Bow
Trippe, DD 403, 341	1320	333	37	345	16	587 W	1183 N	608 W	1300 N	1320	Bow
Rhind, DD 404, 341	2240	313	41	317	09	1619 W	1546 N	1625 W	1663 N	2240	Port Bow
Stack, DD 406, 341	2003	317	41	322	28	1350 W	1483 N	1360 W	1595 N	2003	Port Bow
Wilson, DD 408, 341	1766	322	29	329	29	1075 W	1400 N	1092 W	1517 N	1766	Port Bow
Hughes, DD 410, 348	643	81	58	97	10	637 E	90 N	607 E	202 N	635	Stbd. Beam
Anderson, DD 411, 348	Sunk during Test A										
Mustin, DD 413, 348	1280	78	45	86	18	1257 E	250 N	1239 E	365 N	1280	Stbd. Beam
Wainwright, DD 419, 348	2952	302	56	314	25	2478 W	1605 N	2501 W	1719 N	2952	Port Bow
Submarines											
Skipjack, SS 184, 299	808	179	30	273	30	7 E	808 S	90 W	813 S	800	Port Beam
Searaven, SS 196, 310	1419	194	49	318	49	362 W	1370 S	446 W	1427 S	1419	Port Bow
Tuna, SS 203, 299	1800	213	03	340	24	981 W	1509 S	1061 W	1574 S	1800	Bow
Skate, SS 305, 311' 6"	886	228	30	324	28	670 W	584 S	775 W	594 S	886	Port Bow
Apogon, SS 308, 311' 6"	846	207	31	303	10	392 W	751 S	487 W	761 S	846	Port Bow
Dentuda, SS 335, 311' 6"	1466	220	16	31	52	947 W	1118 S	962 W	1215 S	1466	Stbd. Bow
Parche, SS 384, 311' 6"	1670	229	00	210	58	1260 W	1095 S	1229 W	994 S	1580	Port Qtr.
Pilotfish, SS 386, 311' 6"	363	68	07	186	25	336 E	135 N	246 E	88 N	260	Stern
Landing Craft											
LST 52, 328	1546	8	09	27	27	220 E	1531 N	195 E	1638 N	1546	Stbd. Bow
LST 133, 328	723	61	58	152	16	639 E	340 N	525 E	339 N	630	Stbd. Qtr.

* Length of Ship in Feet.

TOP SECRET

TABLE 20.1. RELATIVE POSITIONS OF TARGET VESSELS ON B-DAY AT MIKE HOUR. (Con't)
Note: All distances are horizontal distances from actual projected Zeropoint.

Vessel		Range fm Burst to Bow (Yd)	True Bearing of Bow from Burst		Relative Bearing of Burst from Bow		Coordinates of Vessel from Burst (Yd)				Distance from Burst to Nearest Part of Vessel (Yd)	Direction of Burst from Vessel
							Bow		Stern			
			deg	min	deg	min	X	Y	X	Y		
Landing Craft (con't.)												
LST 220,	328*	3466	00	10	13	10	Incomplete Information					
LST 545,	328	4143	358	15	341	45	Incomplete Information					
LST 661,	328	2653	02	00	3			"		"		
LCI 329,	159	3266	74					"		"		
LCI 327,	159	2433	79					"		"		
LCI 332,	159	1873	86	35	275	15	1871 E	112 N	1881 E	59 N	1870	Port Beam
LCI 549,	159	3933	74				Incomplete Information					
LCT 705,							4160 W	473 S	Incomplete Information			
LCT 745,	120						Incomplete Information					
LCT 816,	120	798	56	40	72	37	667 E	438 N	660 E	478 N	798	Stbd. Bow
LCT 818,	120	1396	34	00	241	32	782 E	1159 N	797 E	1121 N	1370	Port Qtr.
LCT 874,	120	2426	48				Incomplete Information					
LCT 1013,	120						4070 W	684 N	Incomplete Information			
LCT 1078,	120	2933	47				Incomplete Information					
LCT 1112,	120	3500	47					"		"		
LCT 1113,	120	4300	49					"		"		
LCT 1114,	120	483	20	13	28	03	167 E	453 N	160 E	493 N	483	Stbd. Bow
LCT 1115,							3407 W	2336 S	Incomplete Information			
Merchant Craft												
Gilliam, APA 57,	426	Sunk during Test A										
Banner, APA 60,	426	2499	264	07	281	15	2487 W	256 S	2527 W	118 S	2490	Port Beam
Barrow, APA 61,	426	2054	268	08	279	48	2053 W	66 S	2059 W	74 N	2049	Port Beam
Bladen, APA 63,	426	2623	169	01	185	27	498 E	2567 S	458 E	2427 S	2480	Stern
Bracken, APA 64,	426	1560	156	55	164	30	612 E	1436 S	592 E	1294 S	1420	Stern
Briscoe, APA 65,	426	950	133	03	237	08	695 E	649 S	556 E	684 S	878	Port Qtr.
Brule, APA 66,	426	867	295	51	310	46	781 W	378 N	817 W	517 N	867	Port Bow
Butte, APA 68,	426	2785	258	58	276	06	2737 W	534 S	2777 W	397 S	2780	Port Beam
Carlisle, APA 69,	426	Sunk during Test A										
Carteret, APA 70,	426	3229	254	52	277	13	3117 W	843 S	3175 W	710 S	3218	Port Beam
Catron, APA 71,	426	1326	146	18	149	52	737 E	1104 S	727 E	963 S	1210	Stbd. Qtr.
Cortland, APA 75,	426	3875	248	30	276	45	3622 W	1392 S	3683 W	1266 S	3870	Port Beam
Crittenden, APA 77,	426	1686	273	33	282	55	1684 W	105 N	1707 W	248 N	1686	Port Beam
Dawson, APA 79,	426	1190	283	59	299	09	1155 W	288 N	1194 W	428 N	1190	Port Bow
Fallon, APA 81,	426	466	302	59	330	38	391 W	254 N	456 W	379 N	466	Port Bow
Fillmore, APA 83,	426	2150	163	04	172	02	627 E	2058 S	603 E	1916 S	2012	Stern
Gasconade, APA 85,	426	716	152	51	165	33	326 E	637 S	263 E	498 S	580	Stern
Geneva, APA 86,	426	2920	171	10	196	56	446 E	2880 S	386 E	2743 S	2780	Port Qtr.
Niagara, APA 87,	426	3186	174	11	201	35	323 E	3170 S	260 E	3042 S	3060	Port Qtr.
Concrete Drydocks & Barges												
YO-160,		543	105	30	190	30	524 E	145 S	399 E	132 S	425	Stern
YOG 83,		1090	321	10	21	45	684 W	849 N	795 W	912 N	1090	Stbd. Bow
ARDC 13,		1276	27	25	114	45	587 E	1132 N	457 E	805 N	1217	Stbd. Qtr.

* Length of Ship in Feet.

TOP SECRET

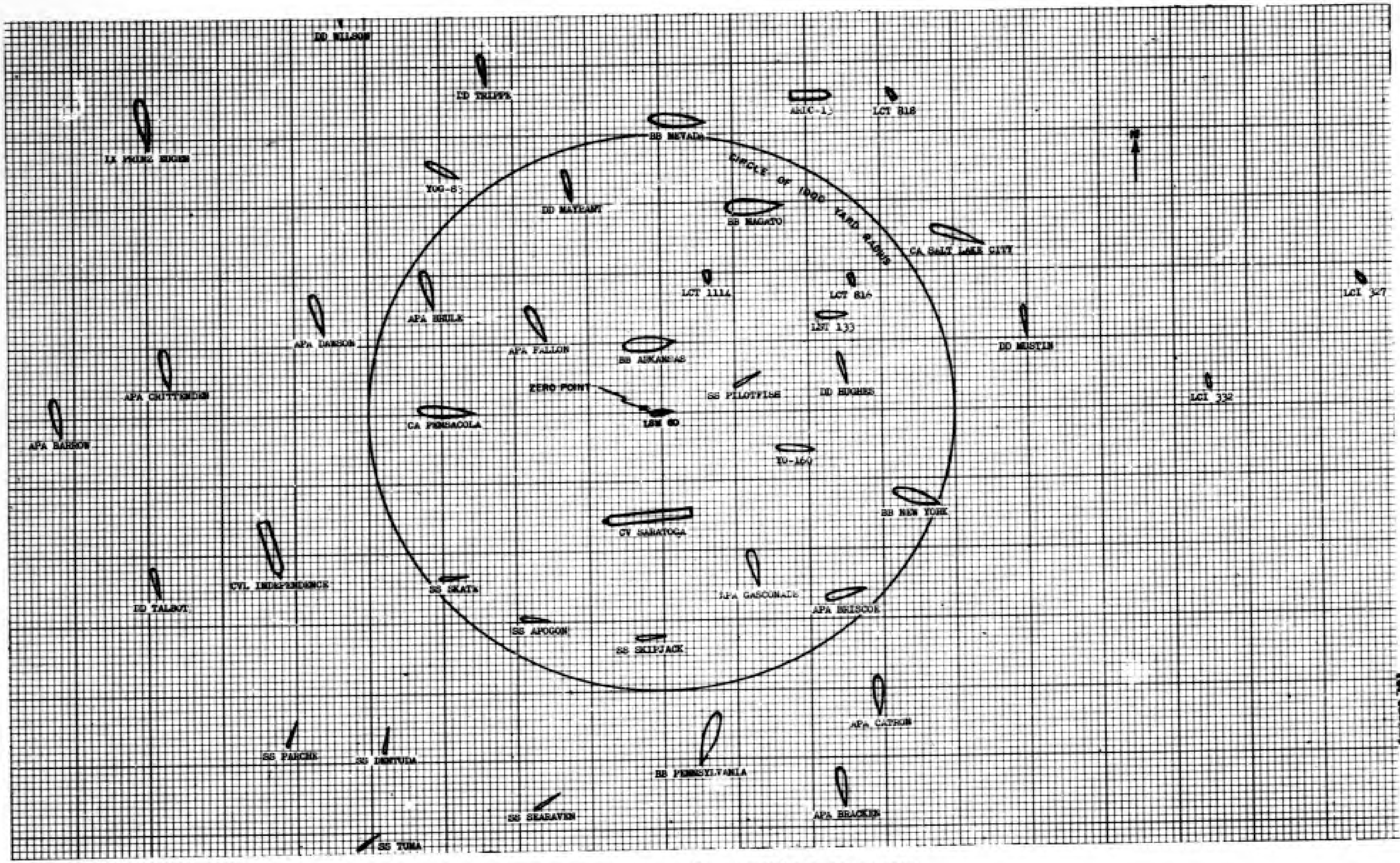

FIGURE 20.1. TEST B TARGET ARRAY [INNER PORTION] SHOWING POSITIONS OF TARGET VESSELS RELATIVE TO PROJECTED ZEROPOINT ON B-DAY AT MIKE HOUR.

TABLE 20.2

Test B Fuel and Ammunition Loads on Target Vessels Within 1000 Yd

Note: Percentages refer to percentage of normal load, abbreviated N. Normal load ordinarily means approximately 95 percent of capacity. M indicates minimum load, ordinarily approximately 10 percent of capacity.

Target Vessel	Fuel Load (percent)	Ammunition Load (percent)
Battleships & Cruisers		
Arkansas	50	50
Nagato	15	M
New York	M	M
Pensacola	15	67
Aircraft Carriers		
Saratoga	M	67
Destroyers		
Hughes	15	67
Mayrant	50	50
Submarines		
Apogon	50	50
Pilotfish	N	N
Skate	33	67
Skipjack	50	50
Landing Craft		
LST 133	M	M
LSM 60	-	-
LCT 816	*	*
LCT 1114	*	*
Merchant Craft		
Briscoe	M	M
Brule	M	M
Fallon	N	N
Gasconade	N	N
Concrete Drydocks & Barges		
YO 160	*	*

* No ammunition aboard; no information available in DSM office as to the actual amount of fuel aboard.

20.005 Status of Actual Array of Other Targets.

A. Airborne Targets. Four Army and three Navy drones were airborne on B-Day at Mike Hour. They were located as follows:

Drone	Altitude (ft)	Approx. Slant Distance from Zeropoint (nautical mi)	Bearing from Zeropoint (Degrees True)
B-17 Fox	6000	1	267
B-17 George	16000	3	267
B-17 How	7000	13	090
B-17 Love	11000	19	090
F6F Red Dog	14000	20	315
F6F White Dog	9000	20	315
F6F Blue Dog	5000	20	315

B. Shore Targets. Eighteen landing craft were exposed on the beach at Bikini, between 5500 and 6000 yd from Zeropoint. These included:

TYPE	QUANTITY	IDENTIFYING NUMBER
LST	1	125
LCI	2	615, 620
LCT	4	412, 812, 1187, 1237
LCM	5	1, 2, 3, 4, 6
LCVP	6	7, 8, 9, 10, 11, 12

C. Other Targets. Two PBY3 seaplanes were on the surface between 2500 and 3500 yd from Zeropoint; bearing approximately 272° true.

20.006 Status of Air and Water.

A. Air. The Equatorial Front was north of Bikini on B-Day, Mike Hour. There was a light (7 knots) southeasterly wind at the surface, shifting with altitude through east to moderately strong northeasterlies above 35,000 ft. At low altitudes the cloud cover was approximately two-tenths (cumulus); there were no clouds at intermediate altitudes, and the cover above 30,000 ft was approximately one tenth (cirrus). Surface air temperature was 86°F., and relative humidity was 73 percent.

B. Water. Within the Lagoon a state ONE sea condition existed (waves less than 1 ft high), water temperature was 82°F., and salinity was 34.75 g per kg. There was a wind-driven surface current running west northwesterly at a speed of 0.15 knot, and a subsurface (below 40 ft) current running easterly at less than 0.1 knot.

20.007 Status of Personnel.

Practically the entire complement of personnel in the Bikini area observed the explosion. Nearly all persons were aboard the non-target vessels, some were aboard planes. No persons were aboard target vessels.

Nearest non-target vessels, (at 8 to 10 mi from Zeropoint) were:

MT. MCKINLEY, CUMBERLAND SOUND, ALBEMARLE, HAVEN, WHARTON, KENNETH WHITING, AVERY ISLAND, BLUERIDGE, BEGOR, HENRICO, WALKE, LAFFEY, O'BRIEN, BARTON, PANAMINT.

The nearest manned plane at Mike Hour was an F-13 (modified B-29) photographic plane, at an altitude of 30,000 ft and a slant range of approximately 6 nautical mi from Zeropoint.

20.008 Re-entry.

Re-entry into Enyu Channel was accomplished rapidly and without incident. The radiological reconnaissance PGM's were the first manned craft to re-enter the Lagoon. Following them (at 1015) came the ships of Task Unit 1.2.8, carrying the radiological safety patrol small craft. At 1230 FALL RIVER took station in Enyu Channel and vessels of Task Unit 1.2.7 (Salvage Unit) entered the Lagoon. MT. MCKINLEY entered the channel at 1700.

Within two hours after Mike Hour, drone boats had penetrated the target array area, and before dark, four individual forays had been made by drone boats. Water samples were collected, brought to ALBEMARLE, and taken by her to Kwajalein to be analyzed for radioactivity. Drone boat activities continued through 29 July.

The technical non-target vessels re-entered the Lagoon on the afternoon of B-Day (25 July) and anchored in the lower anchorage near the Lagoon entrance. On 27 July, they moved to their permanent berths near the target array; but on 28 July they were forced back down to the lower anchorage by an upswelling of radioactivity in the vicinity of the target array. On 30 and 31 July all vessels, including the non-technical vessels which had remained under way in the evacuation operating areas outside the Lagoon since B-Day, returned to their permanent berths. Vessels in the northern part of the anchorage accumulated considerable radioactivity in their evaporators, and on 2 Aug were shifted to uncontaminated berths near the Lagoon entrance, where they remained until 7 Aug.

The "Red Line" and "Blue Line," demarking respectively areas of severe (1 roentgen per day) and moderate (0.1 roentgen per day) exposure were determined and plotted on charts; new charts were made every few hours, at first, and then at less frequent intervals. These lines sometimes advanced, sometimes receded; and as the lines moved, the radiological safety teams, damage control teams, salvage teams, and key observers took advantage of whatever opportunities arose to inspect and service the target vessels.

By nightfall on B-Day initial boarding teams had boarded twelve of the outer target vessels; five days later, 35 vessels had been thus boarded; and by 5 Aug 46, each vessel had been thus boarded at least briefly.

Drone planes had, of course, "re-entered" the target-array area immediately after the detonation. In fact, one such plane was within a mile of Zeropoint at Mike Hour and received very strong shock. All drone planes collected air samples, Navy drones returning with their samples to Roi and Army drones returning to Eniwetok. Samples were transferred to Kwajalein for analysis.

First manned planes to fly into the immediate vicinity of the target array after the detonation were two PBM's, "CHARLIE" and "DOG," which moved in from their 5-mi-distant orbiting positions to observe damage and measure radioactivity. PBM "CHARLIE" made its first report on sinkings about 30 min after Mike Hour, and thereafter many flights across the array were made, principally for photographing the demise of SARATOGA. (The sinking of NAGATO occurred at night and was not observed or photographed.)

The inspection of vessels and instruments and the removal of animals were carried out rapidly after the vessels were reboarded. Recovery of animals was completed five days after B-Day.

The day after B-Day, HUGHES, which was low in the water, was beached by Task Unit 1.2.7; two days after B-Day, FALLON, which was low in the water and listing, was beached.

Decontamination processes were started promptly. For some of the most highly contaminated vessels decontamination measures were continued intermittently for several months. In some cases decontamination activities are expected to continue into 1947.

Instruments and animals were examined immediately after recovery; photographic film was processed and analyzed; and voluminous technical reports were rapidly prepared.

20.009 Sinkings.

Salient data on sinkings and times of sinkings are recorded below: (See a later chapter for details.)

LSM-60 was disintegrated at Mike Hour. Fragments were noticed to splash in several sectors of the array during the first minute after Mike Hour.

ARKANSAS (BB-33) sank within a few seconds after Mike Hour, while still obscured by spray and steam. She was crushed as if by a tremendous hammer blow from below.

YO-160 (concrete oil barge) was seen in photographs taken immediately after Mike Hour and had disappeared when the base surge had passed. She was swamped by the outrushing wall of water.

PILOTFISH (SS-386) (submerged at a keel depth of approximately 56 ft) is believed to have sunk immediately after Mike Hour according to evidence obtained by divers and underwater photography.

SKIPJACK (SS-184) (submerged at a keel depth of 75 ft) was found on the bottom after Mike Hour with her hull plating cracked and several compartments flooded.

APOGON (SS-308) (submerged at a keel depth of 100 ft) was found on the bottom after Mike Hour, with holed bulkheads at several frames and with practically all compartments flooded.

SARATOGA (CV-3) sank by the stern approximately 7½ hr after Mike Hour. The appearance of the shell at the turn of the bilge indicates that she probably suffered very severe damage along the bottom and along the starboard side.

NAGATO (EX-JAP BB) with her hull holed in numerous places, sank during the night of 29-30 July, four days after B-Day.

Chapter 21

Summary of Results of Test B

Outline

Chapter 21

Summary of Results of Test B

21.001 Introduction.

Bomb B detonated 90 ft below the surface of Bikini Lagoon at 59.7 sec (± 0.1 sec) after 0834, 25 July 46, Bikini Local Time. Seventy four target vessels were exposed to the explosion; their positions were as shown in Table 20.1 of Chap. 20.

21.002 Energy Release.

The amount of energy released was "normal" for an atomic bomb of the Nagasaki type; a total of 8.5 X 10^{20} ergs of energy was released, which is equivalent to the total amount of energy released in the exploding of 20.3 kilotons of TNT.

21.003 Damage to Vessels.

A total of 9 vessels sank or capsized as a result of the explosion; they were situated in the range: 0 to 845-yd horizontal distance from the projected Zeropoint. (Distances are measured to nearest point of vessel.) Five (non-sunk) vessels were immobilized; they were situated at ranges from 465 yd to 640 yd.

Three other vessels, at ranges of 815 to 1030 yd, suffered at least temporary serious loss of military efficiency.

21.004 Other Damage.

Moderate damage was inflicted on a B-17 drone flying 6000 ft directly above the Zeropoint.

Special radio and radar equipment exposed on decks of surface vessels was severely damaged at ranges as great as 700 yd. Data are lacking as to damage between 700 and 2000 yd. No important damage was suffered by deck-loaded equipment at 2000 yd or by equipment ashore at 5700 yd.

21.005 Injury to Animals and Plants.

Although the animals were all situated in interior rooms on vessels located upwind from the Zeropoint, the great majority of them had died by 1 Nov 46. In nearly all cases, cause of death was gamma radiation. Dosages received varied from 310 roentgens (BRACKEN, at 1420 yd) to 2700 roentgens (GASCONADE, at 580 yd).

Many of the fish in the northeast corner of the Lagoon were killed by the explosion.

21.006 Pressure Data.

Values of peak pressure in the water half-way between surface and bottom were 7000, 4400, 1400, and 330 psi gage at 835, 1084, 2060, and 5000-ft, respectively, horizontal distance from the projected Zeropoint. At short ranges the pressure was somewhat less just beneath the surface than at greater depth.

The underwater shock wave had a velocity not appreciably different from the normal acoustical velocity.

Peak pressure in air was 4.8 psi gage at 1000-yd horizontal distance, or about the same as would have resulted from an air burst using 4 kilotons of TNT.

21.007 Radiation and Radioactivity.

Optical radiation was negligible.

Nuclear radiations, particularly gamma-radiation, were very important. Between 10 and 50 percent of the radioactive material formed remained in the water or on target vessels. Total activity in the area corresponded (at one hour after Mike Hour) to roughly 5×10^9 curies (5000 megacuries), the approximate momentary equivalent of roughly 5000 tons of radium. Total radioactivity diminished approximately according to a $1/T^{1.3}$ law.

The area initially contaminated extended roughly 1800 yd upwind, 2 mi to each side, and downwind for 2 to 5 mi. Near the Zeropoint, the activity in the water decreased from about 400 roentgens per 24 hrs at one hour after Mike Hour to 0.1 roentgens per 24 hrs at five days after B-Day. Convection contributed, of course, to this decrease.

All but 9 of the target vessels were highly contaminated by the radioactive "rain" and base surge. Total gamma radiation dosages topside on the contaminated vessels ranged from roughly 300 roentgens to over 8000 roentgens. Typically, 50 percent of the dosage was "delivered" within the first 5 or 10 min; lethal dosages (400 roentgens) were delivered within 1 to 7 min in most cases.

In most (but not all) contaminated vessels, radioactivity below decks was less than ½ or even 1/10 as intense as topside.

Plutonium contamination of target vessels was sufficiently great to constitute a serious danger to persons boarding the target vessels days, weeks, or even months after B-Day (i.e., persons not already doomed by gamma radiation).

Decontamination efforts met with varying success. Earliest efforts (involving washing away loose materials) reduced the radioactivity by a factor of 2 to 5; but subsequent efforts produced smaller improvements.

Plutonium and radioactive fission products in the water were a danger to support vessels, since they tended to accumulate in evaporators and elsewhere.

21.008 Other Results.

The water directly above the bomb rose initially at a rate of 11,000 ft/sec. The height of column and cauliflower was 4100 ft at 10 sec and 7600 ft at 60 sec. Radius of the stem was 975 ft. Roughly 2,000,000 tons of water was contained in the column and cauliflower; the potential energy involved was approximately 10 percent of the total energy released in the explosion.

The condensation cloud reached its maximum radius (about one mile) at 4 sec after Mike Hour. By 30 sec it was essentially nonexistent.

The base surge formed approximately 10 sec after Mike Hour, and swept outward at 45 mi/hr, engulfing the majority of the target vessels in its radioactive mist. It attained a radius of approximately 8000 ft, and an altitude of approximately 2000 ft.

Waves had a maximum trough-to-crest height of 94 ft at a range of 1000 ft, (horizontal distance from Zeropoint), and 9 ft at 12,000 ft. The first wave travelled with a velocity of 45 knots. The waves represented less than one percent of the total energy released in the explosion.

Waves probably made significant contributions to damage on at least five target vessels.

The crater produced in the Lagoon bottom was 25 ft deep; the net amount of bottom material moved was over 2,000,000 yd^3.

The explosion was detected at great distances (e.g., Continental U. S.) by earth shock and by radioactivity in the air.

21.009 Correlations.

The following table presents estimates by the JTF-1 Technical Historian as to ranges at which specified loss of military efficiency during the first hour after Mike Hour is probable:

Extent of Immediate Loss of Military Efficiency	Range (yd) Typical Ship Itself	Typical Crew Per Se	Ship and Crew in Combination
Very Serious	700	600	800
Serious	900	800	950
Moderate	1000	1000	1300
Slight	1500	2000	2000

The corresponding ranges for long term (i.e., first month) loss of military efficiency of crew per se are: 2500, 2800, 3200, and 4000 yd.

Injury may be reduced by (1) fleeing from the fall-out and base surge, (2) getting below decks, (3) designing watertight and "quick-shedding," non-porous superstructures, (4) immediately stopping pumps taking water into the ship, (5) promptly washing off exposed areas, (6) detecting and preventing access to "hottest" areas, (7) providing disposable clothing, and (8) transferring crew to uncontaminated ship as soon as possible.

Mechanical and electrical damage to vessels was caused principally by the shock wave in water, and, to a lesser degree, water waves and shock wave in air.

Gamma radiation would have been the outstanding cause of short and long term injury to crews. Topside personnel within 1700 yd would receive lethal (400 roentgens) doses within 1 to 7 min. Considerable harm would result even to personnel on vessels at 4000 yd. Only moderate protection would be afforded personnel below decks on "typical" types of vessels.

Alpha radiation from plutonium inhaled, ingested, etc., may prove fatal over a period of years. Fifty to 100 micrograms may be a fatal dose. Dangerous concentrations may exist on contaminated vessels for months.

21.010 Discussion.

There were no technical or operational shortcomings of any significance; the Test was an entire success. The bomb was detonated at the correct time and position, and extensive graded damage was produced as desired. The instrumentation program was completed very satisfactorily; damage inspection was completed as promptly as radiological clearance permitted.

The very great importance of radioactive contamination by fission products was fully explored, and the insidious potentialities of plutonium contamination were brought to light. The Test was the world's fifth test of the atomic bomb, but it was the first test in which the radioactive "poisonous" material remained in the "biosphere," and thus presented a lingering and invisible menace to man and other forms of life.

A beginning was made at developing methods of decontamination; radioactive vessels were made available for continuing research and training in radiological decontamination, a field now known to be of prime importance.

Chapter 22

Detonation and Energy Release, Test B

Outline

Section

Chapter 22

Detonation and Energy Release, Test B

22.001 General Appearance.

Only a brief account of the appearance of the detonation is given here. Later chapters discuss in detail the column, cloud, etc.

At 59.7 seconds (plus or minus 0.1 sec) after 0834 on 25 July, 46, Bikini local time, Bomb B was detonated, and observers approximately 10 mi away witnessed a giant and unprecedented spectacle. The column shot upward, with a small amount of orange-red light emerging for 0.2 sec. At 1 sec after Mike Hour -- long before the column had achieved its full height -- the condensation cloud began to form.

As the column and cauliflower reached their fully-developed forms, the collapse (descent) began; the column spikes began to move downward; the cauliflower periphery began to curve outward and downward, shadowing a large area of the target array.

The base surge formed as the column plunged back into the Lagoon; a wall of spray, foam, and fog swept outward at 45 mi/hr, engulfing several of the larger target vessels.

After gravity had drained most of the water from the column and cauliflower, a mass of fog and murk lay over the area, obscuring the majority of the target vessels.

The wind slowly carried this mass to the northwest, and for over an hour it could be followed readily by the eye, as a slightly-orange-tinted cloud. Within 2 hr the cloud could no longer be distinguished from the normal clouds dotting the horizon.

Within a few minutes of Mike Hour white lines (bomb-produced surf) on beaches and reefs were apparent to the naked eye of the observers, 10 mi away.

The target area appeared almost entirely clear of clouds and murk by 1 hr after Mike Hour.

22.002 Total Energy Release.

The best value for the total amount of energy released by the explosion is 8.5×10^{20} ergs, which corresponds to the total amount of energy released in the explosion of 20.3 kilotons of TNT. The figure is based on the radiochemical method described in Chap. 5. The probable error is: plus 2 percent, minus 3 percent.

22.003 Partial Energy Release.

Collateral values of equivalent-TNT-tonnage are given below. They are not ordinarily strictly indicative of the total amount of energy released. Their significance is discussed in Chap. 5 and also in Refs. 500 and 300-4.

Parameter Measured	Type of Gage Used	Equivalent-TNT-Kilotons	Source (Ref.No.)
Pressure in Water	Ball Crusher	15 to 20	300-4
Pressure in Air	Foil	4	300-4
Pressure in Air	Diaphragm Strain	4	300-4
Pressure in Air	Airborne Condenser	12	300-4
Duration of Chain Reaction Gamma Timing		"normal"	300-23
Column radius	Camera	9	300-27

22.004 Utilization of Energy.

No comprehensive information is available as to the utilization or apportioning of the energy transmitted in the optical radiation, nuclear radiation, shock wave, or existing as heat.

Chapter 23

Damage to Vessels, Test B

Outline

Section

Chapter 23

Damage to Vessels, Test B

23.001 Introduction.

This Chapter includes a brief discussion of the significant damage suffered by the principal target vessels in Test B. (For a detailed and comprehensive description of damage see Ref. 420-4.)

Distance figures included are in each case the horizontal distance of the projected actual Zeropoint from the nearest point on the vessel.

Generalizations as to range and damage severity are provisional; they are estimates by the JTF-1 Technical Historian. They have been discussed with BuShips representatives, but are not necessarily endorsed by them.

Damage caused by flooding that would easily have been prevented by the ship's force is not here regarded as damage properly attributable to the explosion.

Similarly, damage which was primarily the result of damage produced in Test A is not considered to be damage properly attributable to Test B; such damage is alluded to only for general information.

Radioactive contamination of vessels is not considered damage to vessels, and is not discussed in this Chapter. (See, however, Chap. 29.)

23.002 Loss of Military Efficiency in Test B.

A. Very Serious Loss of Military Efficiency.

1. Ships Sunk or Capsized. Nine vessels (including the bomb carrier LSM-60) were sunk or capsized in Test B. The vessels were:

Vessel	Horizontal Distance from Zeropoint (yd)
LSM-60 (bomb carrier)	0
ARKANSAS (BB-33)	225
PILOTFISH (SS-386)	260

Vessel (con't)	Horizontal Distance from Zeropoint (yd)
SARATOGA (CV-3)	350
LCT-1114	485
YO-160	425
NAGATO (ex-Jap-BB)	745
SKIPJACK (SS-184)	800
APOGON (SS-308)	845

2. Ships Immobilized. Other ships immobilized were:

FALLON (APA-81)	465
GASCONADE (APA-85)	580
HUGHES (DD-410)	635
PENSACOLA (CA-24)	640
LST-133	630

B. Serious Loss of Military Efficiency. Other ships suffering serious loss of military efficiency were:

Vessel	Horizontal Distance from Zeropoint (yd)
MAYRANT (DD-402)	815
NEW YORK (BB-34)	820
NEVADA (BB-36)	1030

Most ships within 900 yd suffered serious loss of military efficiency due to damage to electronic equipment; most ships within 800 yd suffered additional loss of military efficiency due to damage to ordnance equipment.

C. Moderate Loss of Military Efficiency. In general, surface vessels at ranges of 900 to 1100 yd suffered moderate loss of military efficiency. The chief contributing cause of loss of military efficiency in this range was damage to ordnance and electronic equipment.

D. Slight Loss of Military Efficiency. In general, damage to ordnance and electronic equipment caused slight loss of military efficiency out to approximately 1500 yd.

E. Range versus Loss of Military Efficiency. The ranges given below for various specified degrees of loss of military efficiency are such that, at the horizontal range given, it is probable (probability greater than 50 percent) that a surface vessel of unspecified type and orientation will suffer (at least temporarily) the indicated degree of loss of military efficiency.

Extent of Short or Long Term Loss of Military Efficiency	Range (yd)
Very serious	700
Serious	900
Moderate	1000
Slight	1500

23.003 Damage to Hulls.

A. Introduction. This Section discusses damage to hulls, here considered to include decks, sides, bottoms, and superstructures of vessels.

B. Description of Damage.

1. Battleships. ARKANSAS (225 yd), battleship closest to the actual Zeropoint, received very extensive hull damage; large holes were made, and she flooded immediately and sank within one minute. Her sideshell plating gave at numerous points, rivets failing at seams and butts. Her bottom was badly indented (6 or more feet at some points). Her rudder and screw were lost. Her sides above the waterline showed little or no damage. NAGATO (745 yd) sank in 4½ days with a hole 2 ft in diameter above her port bilge keel and 7 other major leakage points. NEW YORK (820 yd) suffered moderate hull damage; she had open seams in her underwater shell plating and in three of her tanks. There was minor flooding. Holding-down clips were fractured on three of her turrets. NEVADA (1030 yd) experienced minor dishing of her hull; the holding-down clips on one turret were sheared. The remaining battleship, PENNSYLVANIA (1105 yd), received no significant hull damage.

2. Cruisers. PENSACOLA (640 yd) received moderate hull damage. This damage was confined largely to areas where her hull structure had been weakened in Test A. She suffered dishing of shell plating and damage to holding down-clips, battery mounts, bulkheads, stanchions, and machinery foundations. SALT LAKE CITY (1120 yd) suffered only minor hull damage. PRINZ EUGEN (1990 yd) was undamaged.

3. Destroyers. HUGHES (635 yd), destroyer nearest the actual Zeropoint, suffered major structural damage involving flooding due to ruptured piping and fractured sea connections. Her shell plating was slightly dished, rudder and skeg were severely damaged, and the foundation supporting one end of the low-pressure turbine was distorted. MAYRANT (815 yd) received damage to bulkheads, stanchions and weather doors. There was minor flooding caused by broken lines. No other

destroyers suffered significant hull damage.

4. Aircraft Carriers. SARATOGA (350 yd) did not suffer severe structural distortion or hull ruptures, but probably sank from progressive flooding due to a fairly large number of leaking riveted seams. INDEPENDENCE (light-cruiser hull, 1390 yd) suffered minor dishing of her hull.

5. Submarines. PILOTFISH (260 yd), submarine closest to the actual Zeropoint, sank; nearly all compartments flooded, tops of ballast tanks were no longer tight, and the superstructure was dished in. SKIPJACK (800 yd) sank; she had a crack in her athwartship plating on top of torpedo room, tops of ballast tanks leaked, and forward battery and control rooms were flooded. APOGON (845 yd) sank with most of her compartments flooded or partially flooded. There were openings in her bulkheads, hatch cover failed, and a tank top was ruptured. None of the surviving submarines received significant hull damage.

6. Attack Transports. FALLON (465 yd), APA closest to the actual Zeropoint, survived. However, she was flooded to her waterline, suffering severe structural damage to the ship girder. There was buckling of her shell and decks and a permanent transverse-curvature twist in her hull. GASCONADE (580 yd) also suffered loss of longitudinal strength. There was wrinkling in her shell and bottom, and considerable dishing of doors. In addition she experienced partial flooding from broken lines. (Flooding could have been controlled.) BRULE (865 yd) also suffered minor flooding from broken lines but there was no damage to her strength hull. There was some dishing of bulkheads. BRISCOE (880 yd) experienced light dishing of her hull. No other APA's received hull damage.

7. Other Craft. LST-133 (630 yd) suffered minor hull damage and flooding; her ballast tanks were cracked. LST-52 (1545 yd) was unaffected.

LCT-1114 (485 yd) capsized. LCT-816 (800 yd) experienced moderate dishing and flooding from undetermined cause (probable cause: opening of shell seams in engine spaces). LCT-818 (1370 yd) was unaffected.

YO-160 (425 yd) sank almost immediately. YOG-83 (1090 yd) suffered no hull damage.

ARDC-13 (1215 yd) sank due to hull damage experienced in Test A.

C. Loss of Military Efficiency.

1. Battleships. ARKANSAS (225 yd) sank immediately after the

explosion. NAGATO (745 yd) sank approximately 4½ days after the explosion. (It is possible that with ship's force available NAGATO could have been saved.) NEW YORK (820 yd) suffered some loss of watertightness and seaworthiness from minor flooding. (Other flooding affecting her electrical steering could have been controlled by her ship's force.) NEW YORK's military efficiency was seriously impaired due to inoperability of three turrets resulting from failure of holding down clips. Likewise, the military efficiency of NEVADA (1030 yd) was moderately reduced by turret damage. The military efficiency of PENNSYLVANIA (1105 yd) was not impaired by hull damage.

2. Cruisers. PENSACOLA (640 yd) suffered moderate loss of seaworthiness due to significant structural damage to her hull. She suffered serious loss of military efficiency as the result of damage to three of her turrets rendering them inoperable. The military efficiency of SALT LAKE CITY (1120 yd) was not appreciably impaired by hull damage.

3. Destroyers. HUGHES (635 yd) suffered serious loss of military efficiency due to hull damage. Failures of piping, sea connections, and hull fittings caused some loss in buoyancy, stability, and watertightness. Her main machinery was made completely inoperable due to failure of supporting foundations. MAYRANT (815 yd) experienced no serious loss of military efficiency. (She suffered damage to machinery and electrical equipment as the result of flooding which could have been controlled by the ship's force.)

4. Aircraft Carriers. SARATOGA (350 yd) sank in 8 hr. The military efficiency of INDEPENDENCE (1390 yd) was not significantly impaired by hull damage.

5. Submarines. PILOTFISH (260 yd), SKIPJACK (800 yd), and APOGON (845 yd) sank due to hull damage. No other submarine suffered loss of military efficiency due to hull damage.

6. Attack Transports. FALLON (465 yd) suffered serious loss of military efficiency as the result of serious hull damage. GASCONADE (580 yd) also suffered serious loss of military efficiency due to loss of longitudinal strength. Her seaworthiness was greatly affected. The military efficiency of BRULE (865 yd) was not affected by hull damage.

7. Other Craft. LST-133 (630 yd) suffered moderate reduction in military efficiency due to damage to main deck and interior compartments. LCT-1114 (485 yd) sank. LCT-816 (800 yd) suffered serious loss of military efficiency; her stability was adversely affected; flooding occurred requiring beaching. YO-160 (425 yd) sank.

D. Distance versus Damage Relationship. The Test-B distance versus hull-damage data are presented in Table 23.1. The distances given are (as elsewhere in this Chapter) horizontal distances in yards from the projected actual Zeropoint to the nearest part of the vessel. In most cases the distance figure given represents the greatest radius* at which damage of indicated severity actually occurred to target vessels on B-Day. In the "Negligible Damage" columns, however, the value given for each type of vessel is the range of that vessel (suffering negligible damage) which was nearest the Zeropoint. Similarly the "Nearest Surviving Ship" column gives for each type of ship the range of that (surviving) ship which was nearest the Zeropoint. In using the Table, it is convenient to bear this rule in mind: when comparing vulnerability of ships of different type (with respect to damage of specified type and severity), or when comparing vulnerability of different parts of a ship, higher numbers indicate greater vulnerability.

E. Ship Type versus Damage Relationship. Although no reliable conclusions had been reached by 1 Nov 46 as to the relative vulnerabilities of hulls of vessels of different types, there is evidence that battleship hulls are least vulnerable and some suggestion that cruiser hulls are slightly more vulnerable than hulls of destroyers and attack transports. Submerged submarines are relatively vulnerable.

Range of "probable" major hull damage for a surface combatant vessel of "typical" type was approximately 625 yd. Other than battleship NAGATO (745 yd), no ships suffered damage classified as moderate. The range of "probable" minor hull damage for a surface vessel of "typical" combatant type was approximately 950 yd.

F. Engineering Consequences of Damage. In most cases of hull breaching, flooding occurred, causing sinking or damage to machinery and electrical equipment. Other consequences of hull damage were inoperability of machinery caused by damaged machinery foundations, inoperability of propulsion machinery, inoperability of turrets, damage to electrical wiring and electrical equipment, and damage to ordnance equipment.

G. Mechanism Producing Damage. Hull damage was caused by underwater shock, violent motion and impact caused by water waves and air blast.

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* Footnote: If the "sample" of ships had been greater, instances would presumably have occurred where even greater ranges could have been found for damage of specified type. On the other hand, we may now have instances where ships at lesser ranges did not suffer damage of the indicated severity. Thus the ranges here presented are not intended to be ranges for which the probability value equals 50 percent or any other percentage; they are merely observed greatest ranges. On the other hand, they are probably fairly close, in many cases, to "probability-equals-50 percent" ranges given in other sections.

23.004 Damage to Boilers and Stacks.

A. Introduction. Boiler damage in Test B was limited principally to brickwork, boiler foundations, and casings. There was little stack damage. In all cases of boiler damage mentioned in this Section, there was loss of boiler power.

B. Description of Damage.

1. Battleships. NEW YORK (820 yd) suffered very little damage to boilers other than to the boiler casings. Two of her boilers were made temporarily inoperable due to blown out boiler casings. Minor boiler damage occurred on NEVADA (1030 yd) and PENNSYLVANIA (1105 yd).

2. Cruisers. All boilers on PENSACOLA (640 yd) were severely damaged, both brickwork and casings being affected. SALT LAKE CITY (1120 yd) suffered only slight boiler damage.

3. Destroyers. All boilers on HUGHES (635 yd) were seriously damaged. MAYRANT (815 yd) received only minor boiler damage.

4. Aircraft Carriers. INDEPENDENCE (1390 yd) suffered no significant boiler damage. Her temporary stacks, constructed after Test A, were seriously distorted.

5. Attack Transports. FALLON (465 yd) received severe boiler damage. Her boiler foundations were severely stressed and her air casings were ruptured. GASCONADE (580 yd) suffered damage to her boiler brickwork but no damage to boiler casings. No other APA's received significant boiler damage.

C. Loss of Military Efficiency.

1. Introduction. In general, boiler damage resulted in loss of power accompanied by reduced speed and impaired operation of ship's machinery and ordnance, involving serious loss of military efficiency.

2. Battleships. NEW YORK (820 yd) suffered serious loss of military efficiency due to partial loss of boiler power; her speed would have been reduced to approximately 18 knots for a few hours. Boiler damage on PENNSYLVANIA (1105 yd) was not sufficient to prevent steaming. NEVADA (1030 yd) suffered no appreciable loss of military efficiency due to boiler damage.

3. Cruisers. PENSACOLA (640 yd) was immobilized due to boiler damage. Extensive repairs to casings and brickwork would have been required before she could have steamed. SALT LAKE CITY (1120 yd) suffered no impairment of military efficiency as the result of boiler damage.

4. Destroyers. HUGHES (635 yd) suffered serious loss of military efficiency; she was immobilized due to boiler damage. Very extensive repairs would have been required before she could have steamed. MAYRANT (815 yd) suffered no appreciable loss of military efficiency due to boiler damage.

5. Aircraft Carriers. INDEPENDENCE (1390 yd) suffered no loss of military efficiency due to boiler damage.

6. Attack Transports. FALLON (465 yd) suffered serious loss of military efficiency; she was immobilized due to boiler damage. Extensive repair would have been required on these boilers before they could steam again and complete replacement of one of her boilers might have been required. GASCONADE (580 yd) also suffered serious loss of military efficiency; she was probably immobilized due to boiler damage. It is doubtful whether her boilers could have continued operating without replacement of the floor bricks. No other APA's suffered loss of military efficiency as a result of boiler damage.

D. Distance versus Damage Relationship. The distance versus boiler damage data are presented in Table 23.1.

E. Ship Type versus Damage Relationship. It is tentatively suggested that boiler vulnerability of different types of target ships increased in the following order: attack transports (least vulnerable), destroyers and cruisers (about the same), battleships (most vulnerable). The range of "probable" major boiler damage for the above ship types was approximately 625 yd.

F. Engineering Consequences of Damage. Boiler damage was accompanied by loss of power for propulsion and operation of ships' machinery and ordnance.

G. Mechanism of Producing Damage. The boiler damage was caused by the underwater shock transmitted to the boilers through the ships' structures and by air pressure entering the boilers furnaces through the stacks and uptakes. The most serious boiler damage was caused by the underwater shock.

23.005 Damage to Miscellaneous Machinery.

A. Introduction. Damage to main propelling machinery and auxiliary machinery was extensive out to approximately 650 yd. Particularly vulnerable were propelling machinery, steering system, and diesel generators.

TOP SECRET

TABLE 23.1. GREATEST RANGE AT WHICH DAMAGE OF INDICATED SEVERITY WAS PRODUCED IN TEST B.
(Range is horizontal distance in yards from projected zeropoint to nearest part of ship.)

SHIP TYPE AND DISTANCES	SUNK	NEAREST SURVIVING SHIP OF SAME TYPE	HULL (INCLUDING SUPERSTRUCTURE)				BOILERS AND STACKS		MISCELLANEOUS MACHINERY		ELECTRICAL		
			MAJOR DAMAGE	MODERATE DAMAGE	MINOR DAMAGE	NEGLIGIBLE DAMAGE	MAJOR OR MODERATE DAMAGE	MINOR OR NEGLIGIBLE DAMAGE	MAJOR OR MODERATE DAMAGE	MINOR OR NEGLIGIBLE DAMAGE	MAJOR DAMAGE	MODERATE DAMAGE	MINOR OR NEGLIGIBLE DAMAGE
BATTLESHIPS 225, 745, 820, 1030, 1105	745 (NAGATO)	820 (NEW YORK)	225 (ARKANSAS)	745 (NAGATO)	1030 (NAGATO)	1105 (PENNSYLVANIA)	820 (NEW YORK) (MODERATE)	1105 (PENNSYLVANIA)	--	1105 (PENNSYLVANIA)	NO CASES	820 (NEW YORK)	1030 (NEVADA)
CRUISERS 640, 1120, 1390	NO CASES	640 (PENSACOLA)	640 (PENSACOLA)	NO CASES	1120 (SALT LAKE CITY)	1390 (INDEPENDENCE)	640 (PENSACOLA) (MAJOR)	1120 (SALT LAKE CITY)	640 (PENSACOLA) (MAJOR)	1120 (SALT LAKE CITY)	NO CASES	640 (PENSACOLA)	1120 (SALT LAKE CITY)
DESTROYERS 635, 815, 1280	NO CASES	635 (HUGHES)	635 (HUGHES)	NO CASES	815 (MAYRANT)	1280 (MUSTIN)	635 (HUGHES) (MAJOR)	815 (MAYRANT)	635 (HUGHES)	1280 (MUSTIN)	635 (HUGHES)	NO CASES	1280 (MUSTIN)
AIRCRAFT CARRIERS, LIGHT 1390	NO CASES	NO CASES	NO CASES	NO CASES	NO CASES	1390 (INDEPENDENCE)	NO CASES	1390 (INDEPENDENCE)	NO CASES	1390 (INDEPENDENCE)	NO CASES	NO CASES	1390 (INDEPENDENCE)
AIRCRAFT CARRIERS, HEAVY 350	350 (SARATOGA)	NO CASES	--	--	--	--	--	--	--	--	--	--	--
SUBMARINES 260, 800, 845, 885, 1085, 1465	845 (APOGON)	885 (SKATE)	845 (APOGON)	NO CASES	NO CASES	885 (SKATE)	--	--	800 (SKIPJACK)	1465 (DENTUDA)	885 (SKATE)	NO CASES	1600 (TUNA)
ATTACK TRANSPORTS 465, 580, 865, 880, 1190	NO CASES	465 (FALLON)	580 (GASCONADE)	NO CASES	880 (BRISCOE)	1190 (DAWSON)	580 (GASCONADE) (MAJOR)	865 (BRULE)	580 (GASCONADE)	1190 (DAWSON)	465 (FALLON)	580 (GASCONADE)	1190 (DAWSON)
EXPLANATION OF COLUMN HEADINGS	--	--	BUCKLING OF PLATES AND SERIOUS FLOODING OR LOSS OF LONGITUDINAL STRENGTH	MINOR BREACHING OF HULL	DISHING OF SHELL PLATING	DISTANCE OF NEAREST SHIP SUFFERING NEGLIGIBLE DAMAGE	IMPAIRMENT OF BOILER OPERATION	MINOR OR NO DAMAGE	MACHINERY DAMAGE IMPAIRING MILITARY EFFICIENCY	MINOR OR NEGLIGIBLE MACHINERY DAMAGE	ELECTRICAL DAMAGE SERIOUSLY IMPAIRING MILITARY EFFICIENCY	ELECTRICAL DAMAGE MODERATELY IMPAIRING MILITARY EFFICIENCY	MINOR OR NEGLIGIBLE ELECTRICAL DAMAGE

B. Description of Damage.

1. Battleships. NEW YORK (820 yd) had her electric steering system, a diesel generator, and a fire pump rendered inoperative. NEVADA (1030 yd) suffered damage to her main steering unit and after diesel generator. This damage was due to flooding and would not have occurred had there been an uninjured crew aboard. PENNSYLVANIA (1105 yd) suffered only minor machinery damage.

2. Cruisers. The main propelling and auxiliary machinery on PENSACOLA (640 yd) was seriously damaged. SALT LAKE CITY (1120 yd) suffered only minor machinery damage.

3. Destroyers. The main machinery was inoperative on HUGHES (635 yd), partly due to failure of supporting foundations. Main propelling machinery on MAYRANT (815 yd) was inoperative due to minor flooding. This flooding could have been controlled by an uninjured crew. MUSTIN (1280 yd) suffered no appreciable machinery damage.

4. Aircraft Carriers. INDEPENDENCE (1390 yd) did not experience significant machinery damage.

5. Submarines. SKATE (885 yd) suffered serious damage to her main propelling and auxiliary machinery. SEARAVEN (1420 yd) did not experience significant machinery damage.

6. Attack Transports. The machinery plant on FALLON (465 yd) was rendered completely inoperable with serious damage to main propelling and auxiliary machinery. Similar serious machinery damage occurred on GASCONADE (580 yd). BRULE (865 yd) experienced minor machinery damage.

C. Loss of Military Efficiency.

1. Introduction. In all cases of major machinery damage military efficiency was seriously impaired. In general, damage to propelling machinery completely immobilized the ship.

2. Battleships. No battleships experienced serious loss of military efficiency due to machinery damage (other than boiler damage).

3. Cruisers. The military efficiency of PENSACOLA was seriously impaired by machinery damage. She suffered complete loss of propulsion and ship control. SALT LAKE CITY (1120 yd) suffered negligible loss of fighting efficiency due to machinery damage.

4. Destroyers. Military efficiency of HUGHES (635 yd) was seriously impaired due to machinery damage. Damage to main engines

left the ship completely inoperable. If one assumes that flooding on MAYRANT (815 yd) could have been controlled, then she suffered no appreciable loss of military efficiency due to machinery damage.

5. Aircraft Carrier. INDEPENDENCE (1390 yd) did not suffer impairment of military efficiency due to machinery damage.

6. Submarines. No submarines suffered serious significant loss of military efficiency due to machinery damage. However, SKATE's (885 yd) storage batteries were impaired.

7. Attack Transports. The military efficiency of FALLON (465 yd) was seriously impaired by machinery damage. GASCONADE (580 yd) also suffered serious impairment of military efficiency due to serious damage to her main propelling and auxiliary machinery. BRULE's (865 yd) military efficiency was not impaired by machinery damage.

D. Distance versus Damage Relationship. The distance versus machinery damage data are presented in Table 23.1.

E. Ship Type versus Damage Relationship. Submarines suffered at least minor machinery damage at greater range than any other ship type.

F. Engineering Consequences of Damage. In general, serious damage to main propelling and auxiliary machinery caused loss of propulsion and control.

G. Mechanism of Producing Damage. Main propelling machinery and auxiliary machinery suffered from effects of shock and violent motion of the ship. Rapid accelerations in many cases caused shearing and parting of machinery supports.

23.006 Damage to Electrical Equipment.

A. Introduction. Extensive damage to electrical equipment occurred at ranges as great as approximately 600 yd. Especially vulnerable to damage were diesel generators and master gyroscopes.

B. Description of Damage.

1. Battleships. NEW YORK (820 yd) suffered damage (from flooding) to an emergency diesel generator and electric steering motors. Both of her gyro compasses were damaged. NEVADA (1030 yd) had her main steering unit and after diesel generator flooded. This flooding would not have occurred had an uninjured crew been aboard. PENNSYLVANIA (1105 yd) suffered damage to her master gyro and loss of electrical steering gear.

2. Cruisers. PENSACOLA (640 yd) suffered damage to a diesel generator and gyro compasses. SALT LAKE CITY (1120 yd) experienced damage to gyrocompasses due to flooding which could have been controlled had her crew been aboard.

3. Destroyers. HUGHES (635 yd) experienced damage to turbogenerators. MAYRANT (815 yd) suffered damage to pump motors and gyrocompass. MUSTIN (1280 yd) did not receive significant electrical damage.

4. Submarines. Failure of battery cell ventilation on SKATE (885 yd) constituted serious electrical damage. Her master gyrocompass and its follow-up system were rendered inoperable. SEARAVEN (1420 yd) also experienced failure of her master gyrocompass and its follow-up system.

5. Attack Transports. FALLON (465 yd) suffered major damage to her generator and electrical propulsion equipment. The turbogenerator and master gyrocompass on GASCONADE (580 yd) were rendered inoperative. The electrical equipment on BRULE (865 yd) was relatively undamaged.

6. Other Craft. LST-133 (630 yd) suffered serious damage to her electrical plant due to damage to three diesel generator sets. Her gyrocompass was also inoperative. Electrical equipment on LCT-816 (800 yd) was rendered inoperative by flooding.

C. Loss of Military Efficiency.

1. Introduction. The principal effects of electrical damage on military efficiency were: loss of fire control and gunnery due to loss of gyrocompasses; loss of power due to generator damage resulting in loss of electric steering and other electric machinery.

2. Battleships. The military efficiency of NEW YORK (820 yd) was seriously impaired by electrical damage which affected fire control and gunnery. Electrical damage to NEVADA (1030 yd) and PENNSYLVANIA (1105 yd) had only slight effect on military efficiency.

3. Cruisers. PENSACOLA (640 yd) suffered slight loss of military efficiency due to inoperability of diesel generator and gyrocompass. SALT LAKE CITY (1120 yd) experienced loss of after fire control and gyrocompasses due to flooding. This flooding could have been eliminated if an uninjured crew had been aboard.

4. Destroyers. HUGHES (635 yd) suffered slight loss of military efficiency due to damage to turbogenerators. Damage to pump motors and master gyrocompass slightly impaired military efficiency of MAYRANT (815 yd). No other destroyers suffered appreciable loss of military efficiency due to electrical damage.

5. Aircraft Carriers. INDEPENDENCE (1390 yd) suffered no loss of military efficiency due to electrical damage.

6. Submarines. Electrical damage to SKATE (885 yd) in the form of battery cell damage seriously impaired her military efficiency. Only fifty percent of her "submerged power" could be realized. Failure of SKATE's gyroscope follow-up necessitated hand feeding of the course to the topside data computer. SEARAVEN (1420 yd) suffered slight loss of military efficiency due to failure of gyroscope follow-up system.

7. Attack Transports. Electrical damage reduced the military efficiency of FALLON (465 yd) to zero; there was complete loss of propulsion. GASCONADE (580 yd) experienced only slight loss of military efficiency from electrical damage.

8. Other Craft. LST-133 (630 yd) suffered serious loss of military efficiency due to loss of steering and generators. The military efficiency of LCT-816 (800 yd) was seriously impaired because of electrical damage which resulted from flooding.

D. Distance versus Damage Relationship. The distance versus electrical damage data are presented in Table 23.1.

E. Engineering Consequences of Damage. Serious damage to generators caused power failure accompanied by inoperability of all electrical equipment (electric propulsion equipment, electric steering system) lights, fire control system. Damage to master gyrocompass affected ship control.

F. Mechanism Producing Damage. Damage to electrical equipment was caused by flooding, shock, and violent motion of the ship.

23.007 Damage to Ordnance Equipment.

Serious damage to ordnance equipment occurred out to 800 yd. The heavy equipment generally received more damage than the light or medium weight equipment. Damage to holding-down clips seriously affecting turret operation occurred on PENSACOLA (640 yd), NEW YORK (820 yd), and NEVADA (1030 yd). No light weapons were made completely inoperable and the only damage to intermediate caliber guns was on the HUGHES (635 yd).

Fire control equipment received considerable damage on vessels within 700 yd of the bomb. The equipment on HUGHES (635 yd) and PENSACOLA (640 yd) was made almost completely inoperative.

Some gun directors on HUGHES, PENSACOLA, SALT LAKE CITY, and NEW YORK received serious damage.

In general, fire control radars more than 1500 yd from the detonation were undamaged while all those closer than 800 yd were rendered completely inoperable.

A sharp line of demarkation between serious and minor damage to ordnance equipment may be drawn between HUGHES (635 yd) and MAYRANT (815 yd); the former suffered very serious loss of military efficiency of ordnance equipment while the latter sustained only minor damage to ordnance equipment.

23.008 Damage to Electronic Equipment.

Electronic equipment suffered major damage on four ships, light to medium damage in approximately 15 ships, and no appreciable damage on approximately 45 ships. In general, heavy damage was confined to ranges less than 1200 yd. Medium to light damage occurred out to 1500 yd.

Shock and vibration accounted for the majority of the damage. The remaining damage was caused either by falling water from the column or by water used in decontamination.

23.009 Relationship Between Ship Orientation and Damage.

The relationship between ship orientation and damage has not yet been determined. However it is interesting to note the difference in the nature of damage to GASCONADE and HUGHES. The distances from the actual Zeropoint to the centers of these ships were approximately the same; yet GASCONADE (approximately stern-to the explosion) had her longitudinal strength seriously impaired while HUGHES (broadside) suffered little or no loss of longitudinal strength. A possible explanation of this difference is that GASCONADE suffered hogging and sagging from riding perpendicular to the waves while the HUGHES rode parallel to the waves and had her bottom supported by the water at all times.

Chapter 24

Other Damage. Test B

Outline

Section

Chapter 24

Other Damage, Test B

24.001 Introduction.

Special equipment exposed on decks of target vessels became radioactively contaminated (by waves, column fall-out, base surge, etc.) as did the decks of the target vessels on which the equipment was exposed. The area affected and the extent of radioactivity have been described in the previous chapter.

24.002 Damage to Airborne Aircraft.

Damage to airborne aircraft in Test B was limited to the two Army B-17 drones which were almost exactly above Zeropoint at Mike Hour. These planes carried out their missions and landed safely, but were damaged as follows:

Drone	Altitude (Ft)	Slant Range (Nautical Miles)	Damage
Fox	6000	1.0	Bomb-bay doors blown in; rivets pulled through skin; front escape hatch bent; tail-cone window frame bent and window blown in; starter adapter plywood holder in radio room broken; small inspection doors on lower surface of wing blown open.
George	16,000	2.9	Plywood door between bomb-bay and radio room broken; two wing inspection doors hanging open.

According to slow-reading accelerometers possessing considerable lag, drone Fox received accelerations in the neighborhood of plus 12 and minus 6 G. (The accelerometer indicator went off-scale.) Drone George received accelerations in the neighborhood of plus 8 and minus 5 G. (The accelerometer indicator went off-scale.)

24.003 Other Damage.

Severe damage to deck-loaded radio and radar equipment was produced by the pressure wave in air and by solid water impact at distances up to 700 yd.

No operational damage was sustained by deck-loaded equipment at 2000 yd or by equipment ashore at 5700 yd.

No structural damage was sustained by rafts of bridging at 1200 yd or by an amphibious truck at 5500 yd.

No information was available on 1 Nov 46 in the Office of the Director of Ship Material as to damage suffered by special deck-loaded equipment at ranges between 700 and 2000 yd.

Chapter 25

Injury to Animals and Plants, Test B

Outline

Chapter 25

Injury to Animals and Plants, Test B

25.001 Introduction.

A detailed account of injury to pigs and rats exposed in Test B is contained in Ref. 420-6. Details on injury to fish, algae, etc., are contained in Ref. 300-15.

25.002 Injury to Pigs and Rats.

Injury to pigs and rats exposed in Test B is summarized briefly in the following table: (Source: Ref. 420-6; 300-12; also tentative information received orally on 13 Nov 46 from Dr. J. L. Tullis and Dr. P. Scoville.)

Vessel	Dist. from Burst to Nearest Part of Vessel (yd)	Approximate Total Exposure (Roentgens)	Animals Exposed	Animals Recovered Alive	Animals Recovered Dead	Animals Alive 20 Aug.	Animals Alive 1 Nov.
GASCONADE	580*	2700	10 pigs	4	6	0	0
			50 rats	0	50	0	0
BRISCOE	878*	1500	49 rats	47	3	12	9
CATRON	1210*	1500	10 pigs	10	0	0	0
			50 rats	49	1	34	30
BRACKEN	1420*	310	50 rats	26	24	23	17

* upwind

These animals were situated in the surgical operating rooms of the APA's, outboard on the starboard side, two decks below the weather deck.

As indicated in the Table nearly all these animals had died by 1 Nov 46. Deaths of pigs and rats on GASCONADE, BRISCOE, and CATRON were presumably caused by gamma radiation which passed through decks and bulkheads after emanating from contaminated material falling on the vessels; neutron radiation was negligible. Deaths of the rats on

BRACKEN were probably due to destruction of water supplies in some of the cages.

When reached by reboarding teams the most seriously injured (moribund) pigs were capable of little muscular activity; they were unable to stand and were feverish. Less heavily exposed animals were muscularly weak and had diarrhea, increased respiration rate, and hemorrhagic patches on mucous membranes.

These symptoms were mainly the result of destruction of white blood corpuscles by the gamma radiation.

25.003 Injury to Other Life.

The majority of fish in the Lagoon survived. Many in the northeast corner of the Lagoon were killed; many were found which had apparently been killed by the shock; and many others, dead and alive, were found to contain large quantities of accumulated radioactive material.

Concentration of radioactivity was found in corals, algae, shrimp, clams, plankton, and sea urchins. Some fish, clams, and sea urchins were believed to have died from overexposure; extensive damage was done to reef-building corals and calcareous algae by pollution by floating oil.

Minor damage to grasses and Tacca plants on the Lagoon side of Bikini Island occurred due to salt-water flooding by waves. (Source: 300-7)

Outline

Chapter 26

Pressure Data, Test B

Chapter 26

Pressure Data, Test B

26.001 Introduction.

Detailed accounts of pressure produced by Bomb B are contained in Ref. 300 (particularly Ref. 300-13).

26.002 Peak Pressure in Water.

Peak underwater pressures produced are listed below: (Source: Ref. 300-13)

Horizontal Distance from Projected Zeropoint (ft)	Peak Pressure just Beneath the Surface of the Water (psi gage)	Peak Pressure at Depth Half-way between Surface and Bottom (psi gage)
835	4600	7000
928	4200	5900
996	3800	5200
1084	3800	4400
1278	3000	3200
1554	2200	2300
2060	1400	1400
3040	800	800
3700	560	560
5000	330	330

By 1 Nov 46 no estimate of the probable error of these data had been made. It is well known, however, that the underwater pressure varied greatly depending on bottom reflections.

26.003 Duration of Pressure Pulse in Water.

The positive pressure pulse in water lasted one or two milliseconds. (Source: Ref. 300-13; distances and depths not specified.)

26.004 Peak Underwater Pressure Screening by Target Vessels.

Few data were availalbe by 1 Nov 46 as to the "screening" or occultation produced in the underwater pressure wave by the hulls of target vessels.

In one instance, underwater pressure on the remote side of the hull of a target vessel was only 40 percent as great as on the exposed side. (Source: Ref. 300-13; distance of vessel not specified.)

26.005 Velocity of Underwater Shock Wave.

Measured velocity of the underwater shock wave was not significantly different — even at ranges of only a few hundred feet from the Zeropoint -- from the normal acoustical velocity. (Source: Ref. 301)

26.006 Peak Pressure in Air.

Peak pressure in air (outside the column) was similar to what would have been produced by an air burst equivalent to 4000 tons of TNT. Actual values were given below: (Source: Ref. 300-13)

Horizontal Distance from Projected Zeropoint (yd)	Peak Pressure in Air (psi gage)
550	16.
650	9.6
800	6.6
1000	4.8
1200	3.8
1500	2.8

The probable error is 10 percent according to Dr. W. G. Penney, and 25 percent according to JTF-1 Technical Historian.

Chapter 27

Radiation and Radioactivity, Test B

Outline

Chapter 27

Radiation and Radioactivity, Test B

27.001 Introduction.

No detailed data are included as to the amount of optical radiation emerging from the detonation area in Test B, since the amount was negligible. It entirely escaped the notice of many observers, and is shown by high-speed photographs to have been of low intensity and short duration (of the order of 0.1 sec).

On the other hand the radioactivity in the water and on target vessels was extremely important and is discussed in the following sections.

27.002 Nature of the Radioactive Material.

The intense radioactivity in the water was due to (a) fission products, which emitted beta and gamma rays, (b) "unfished" material from the bomb, which emitted alpha rays, and (c) radioactive sodium 24, which emitted beta and gamma rays. The induced radioactivity in the hydrogen and chlorine of sea water was of no practical importance.

27.003 Total Amount of Radioactive Material.

Between 10 and 50 percent of the total amount of radioactive material produced by the explosion remained in the water. The total beta activity in the water of the Lagoon at one hour after Mike Hour was between 1.5×10^9 and 5.0×10^9 curies. On the basis of an estimated 2 to 1 ratio between beta and gamma activity, total (beta plus gamma) activity in the Lagoon at one hour after Mike Hour was between 2.3×10^9 and 7.5×10^9 curies, the approximate (momentary) equivalent of between 2500 and 8300 tons of radium.

27.004 Character of the Radiation.

Alpha particles, beta particles, gamma rays, and neutrons were present in the water of the Lagoon at and after the instant of detonation. Their origins and chracteristics were as indicated below:

A. Alpha Particles. Alpha particles emanated from atoms of "unfished" fissionable material which was widely dispersed by the detonation. They were of low energy and low penetrating power; few of them could have penetrated ordinary clothing. They represented an insignificant fraction of the total ionizing radiation present at any particular time. However, alpha radiation from unfished material entering the human body was an important hazard.

B. Beta Particles. Beta particles emanated from the various fission products of the bomb and from elements in the sea water in which artificial radioactivity was induced by neutron capture. Most of the beta particles had energies below approximately 2.3 Mev. They were not highly penetrating and were capable of inflicting little or no subcutaneous damage on personnel.

C. Gamma Rays. Gamma rays emanated from four distinct sources: (1) the bomb during the detonation process; (2) fission products; (3) atoms which were near the detonating bomb captured neutrons and at once emitted gamma rays; (4) atoms which were near the detonating bomb captured neutrons and emitted gamma rays for a long time afterwards. Gamma rays produced by processes (1), (2), and (3) were of high energy and very great penetrating power; gamma rays produced by process (4) and after the initial stages by process (2) were of lower energy and lower penetrating power. Process (2) was the chief source of gamma radiation on the target vessels and in the water. Gamma rays penetrated air, water, and flesh comparatively readily, but were considerably attenuated by appreciable thicknesses of steel.

D. Neutrons. Neutrons were emitted from the detonating bomb. Steel had little shielding effect against them; water afforded considerable shielding. The neutron flux on the target vessels was negligible since nearly all the neutrons were slowed and absorbed by the sea water.

27.005 Time-Rate of Decay of the Total Quantity of Radioactive Material.

At one hour after Mike Hour, the radioactivity near the surface of the water at Zeropoint was approximately 400 roentgens/24 hr. No single curve is available which describes accurately the time-rate of decay of the total quantity of radioactive materials. Two limiting curves exist. One, based on measurements of gamma radiation aboard target vessels, gives a rate proportional to $1/T^{1.3}$. The other is predicted on a mixture of 20 percent radioactive sodium 24 with a half-life of 14.8 hr and 80 percent fission products decaying at a rate proportional to 1/T. (Percentages are computed with respect to radioactivity.)

Presented below are illustrative values of periods in which radioactivity obeying the $1/T^{1.3}$ law diminishes by half.

Arbitrary Starting Time	Subsequent Period Required for Radioactivity to Diminish by Half
4 hr after Mike Hour	2.5 hr
10 hr after Mike Hour	7.0 hr
1 day after Mike Hour	18.0 hr
4 days after Mike Hour	2.5 days
10 days after Mike Hour	6.5 days
30 days after Mike Hour	20.0 days

27.006 Initial Area of Concentration of Radioactive Material.

Fall out from the cloud caused a "rain" of radioactive material to fall in an area extending about 1800 yd upwind from Zeropoint, almost 2 mi to each side, and downwind for several (perhaps 2 to 5) miles. A negligible amount of radioactivity existed in water outside the Lagoon.

27.007 Concentration as a Function of Depth.

The largest part of the radioactive material to remain in the Lagoon was deposited on the surface of the water by the radioactive "rain"; little, if any, radioactive material was present initially near the bottom. Vertical diffusion was very slow. In certain regions, however, downward moving convection currents produced relatively rapid vertical mixing.

The Table presented below gives the approximate amount of radioactive material in an infinite horizontal sheet of water one cm thick at the depth specified. All values are corrected to 4 hr after Mike Hour, thus eliminating the radioactive decay factor.

Day Sample was Taken	Amount (Kilocuries) at Indicated Depth: 0 ft	10 ft	75 ft	150 ft
2 days after B-Day	570	690	500	150
5 days after B-Day	430	410	190	50

27.008 Over-all Diminution of Radioactive Material in the Target Area Waters.

As an example of the over-all diminution (from all causes) of the amount of radioactivity in the target area waters, gamma radiation at the surface of the Lagoon near the Zeropoint fell from about 400 roentgens/24 hr at one hour after Mike Hour to about 65 roentgens/24 hr by 4 hr after Mike Hour and to less than 0.1 roentgens/24 hr by five days after B-Day.

Decrease in concentration was due to: (a) radioactive decay, (b) diffusion, and (c) convection caused by wind and subsurface currents.

27.009 Radioactivity on the Bottom.

Three days after B-Day radioactivity in the Lagoon-bottom materials was less than one percent of the total radioactivity in the water.

Bottom samples from collections begun on the 6th day after B-Day, showed extremely high radioactivity in a layer of newly deposited sand and mud 4 to 8 in. thick near Zeropoint, and appreciable amounts on the bottom throughout the Lagoon. There was no evidence of activity in the bottom material underneath the new deposit.

27.010 Radioactivity on Target Vessels.

All but 9 of the target vessels were highly contaminated by the radioactive "rain" which resulted from the underwater detonation. This included all vessels within about 1800 yd upwind, 3000 yd crosswind, and more than 4000 yd downwind. Total time-integrated dosages on vessels within 1000 yd were over 8000 roentgens.

Topside personnel within 700 yd would have received lethal dosages (400 roentgens) within 30 sec to 1 min and would have received roughly 20 times the lethal dosage (8000 roentgens) within the first hour; personnel within 1700 yd would have received lethal doses within 7 min, and those within 2500 yd (crosswind or downwind) would have received lethal doses within 3 hrs.

The major part of the contaminating materials deposited on the target vessels was probably deposited from the base surge; thus the arrival of the materials was sudden, and the nuclear radiation dosages effected in the first few minutes after arrival probably were of outstanding importance.

Extrapolation of a decay curve based on later measurements indicates that radioactivity on the BRACKEN (1750 yd upwind) at one hour after Mike Hour was as high as 2500 roentgens/24 hr. By 10 days after B-Day 35 vessels still had average topside readings greater than 1 roentgen/24 hr; and by 11 days after B-Day topside intensity on BRACKEN was still 1.2 roentgens/24 hr.

In general, the most exposed locations on a given vessel were the most highly contaminated. Highest readings were obtained on superstructures and exposed decks. In many instances, small regions of especially intense radioactivity were found.

Cordage, canvas, and other porous articles were much more heavily contaminated than metallic surfaces in the same locations.

Wooden decks appeared to absorb greater quantities of radioactive material than metal ones, but the material was found to be confined to a comparatively thin surface layer.

A number of vessels were covered with contaminated coral sand which had been scoured from the bottom of the Lagoon by the explosion.

Little radioactive material penetrated into the interiors of the target vessels, since, in most cases, hatches and ventilators had been closed. Radioactivity below decks varied from 1/2 to less than 1/10 that observed topside. This radioactivity was primarily caused by material deposited on the outside and consequently decreased toward the centerline and toward the lower decks. On certain vessels, however, leakage of radioactive material did occur into the interiors through incompletely secured hatches or ports, or as a result of damage incurred in Test A. On SALT LAKE CITY, certain areas below decks gave readings as high as 20 roentgens/24 hr as late as 13 days after B-Day. Similar conditions existed on a number of other vessels.

The radioactive material accumulated on the hulls of the submerged submarines was less than that on surface vessels, since these submarines were not exposed to the radioactive "rain." However, the bitumastic on the submarine hulls showed a particular affinity for the fission products, and decontamination was extremely difficult.

27.011 Decontamination Results.

Earliest decontamination efforts succeeded in reducing the radioactivity by a factor of 2 to 5, in most cases. Loose material was relatively easily washed off.

Later decontamination efforts, made after the loose material had already been eliminated, produced much less effect. These later efforts involved scrubbing with lye, foamite, and acid, and in some small areas blasting with sand and soft grits. (Source: Ref. 300-20 Fig. 1, of Appendix VII; also Ref. 420)

27.012 Contamination of Support Vessels.

Support vessels entering contaminated areas of the Lagoon during a period of several weeks after Mike Hour collected appreciable amounts of fission products and "unfished" material. These materials were concentrated in evaporators, salt water lines, and in the organic material on the vessels' hulls. The removal of these materials, which were sufficiently concentrated to present an important hazard to personnel, constituted a serious problem.

Chapter 28

Other Detailed Results of Test B

Outline

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Chapter 28

Other Detailed Results of Test B

28.001 Column and Cauliflower.

A. Height of Dome, Column and Cauliflower. Water rose rapidly at first -- initially at a rate of 11,000 ft/sec. (Source: Ref. 301.) The increase in height continued as indicated below:

Time after Start of Growth of Column (sec)	Height of Column and Cauliflower (ft)
0	0
1.0	2100
2.0	2900
3.0	3400
4.0	3700
5.0	3800
10.0	4100
30.0	5700
60.0	7600

B. Radius of Column. The radius of the base or stem of the column increased rapidly, and then remained nearly constant at approximately 975 ft. (Source: Ref. 510-1)

The radius of the cauliflower (crown) was 2400 ft at 5 sec, and 4300 ft at 60 sec. (Source: Ref. 510-1)

C. Weight of Column. The amount of Lagoon water, spray, and vapor comprising the column and cauliflower was approximately 2, 000, 000 tons. This value may have a probable error corresponding to a factor of 2. (Source: Ref. 302)

This weight of water corresponds roughly to 6×10^7 ft^3 or to the amount of water in a cylinder 1000 ft in radius and 20 ft in height. It corresponds also to a hollow cylinder 1000 ft in radius, 5000 ft in height, and 2 ft in wall thickness. The column contained of the order of 150 times as much water as is contained in saturated (80° F.) air occupying a volume equal to that of the column and cauliflower.

The column contained of the order of 4 ft^3 of water per 1000 ft^3 of column. (Source: Ref. 302)

D. Energy in Column. If one arbitrarily assumes that 2,000,000 tons of water was raised 1000 ft, the potential energy of the water was roughly 6 X 10^{19} ergs or roughly 10 percent of the energy released by the bomb. (Source: Ref. 302)

E. Radioactivity. Between 50 and 90 percent of the fission products remained in the cloud and surrounding air, and were carried away from the Bikini area. Ten to 50 percent of the fission products remained in the Lagoon area. (Source: Ref. 300-7)

No data were available in the Office of the Technical Director by 1 Nov 46 as to the intensity of radioactivity in the column or cauliflower.

F. Demise. The cloud remaining, after the column and cauliflower stage was terminated, drifted with the wind towards the northwest, and for over an hour the cloud could be followed readily by eye. The cloud was tinted orange. Within 2 hr after Mike Hour it could no longer be distinguished from the normal clouds dotting the horizon.

28.002 Condensation Cloud.

The condensation cloud had started forming by one second after Mike Hour; by 2.5 sec after Mike Hour it had reached the "birthday cake on a platter" stage; and by 4 sec after Mike Hour it had reached its maximum size (radius of roughly one mile).

By 18 sec after Mike Hour it had become ring-formed, then stratified and broken up into small fragments; and by 30 sec after Mike Hour it was essentially non-existent. (Source: Ref. 510-1)

28.003 Base Surge.

At about 10 sec after Mike Hour, as the column water began to plunge back into the Lagoon, the base surge, or toroidal region of spray, foam, and air formed about the base of the column. It swept and billowed outward at 45 mi/hr, engulfing the majority of the target vessels. It attained a thickness (altitude) of approximately 2000 ft, and an outer radius of approximately 8000 ft. Presumably, it was highly radioactive. (Source: Ref. 510-1)

28.004 Water Waves.

A. Height. Maximum height (trough to crest) of waves was as indicated below: (Source: Ref. 300-16)

Horizontal Distance from Zeropoint (ft)	Maximum Height (ft)
1000	94
2000	47
4000	24
6000	16
8000	13
10,000	11
12,000	9

B. Arrival Time. Arrival times of the first wave at various distances were as follows:

Horizontal Distance from Zeropoint (ft)	Arrival Time (Sec after Mike Hour)
1000	7
2000	20.5
4000	47.5
6000	75
8000	102
10,000	129
12,000	156

C. Velocity. At distances of 1000 to 12,000 ft from the Zeropoint the first wave travelled with a velocity of roughly 45 knots, the velocity expected for a long wave in water 170 ft deep. Velocities of subsequent waves were less. Velocities decreased as the waves entered shallow water.

D. Stability. Near the Zeropoint, the first (highest) wave was unstable, i.e., breaking; farther out, it was stable. On reaching shallow water as at Bikini beach, it became shorter and higher, and thus again became unstable and broke.

E. First Wave versus Later Waves. The first wave proceeded essentially as a solitary wave; at ranges greater than 700 ft its height decreased inversely with distance from the projected Zeropoint. Within 8000 ft of the Zeropoint this wave was higher than any other wave in that area.

Just outside the 8000-ft range the second wave was higher than the first; at somewhat greater range, the third wave was the highest; and so on for succeeding waves, in accordance with the usual phase-velocity versus group-velocity relationship.

Heights of these later waves did not decrease as rapidly with distance as did the height of the first wave.

F. Range for Greatest Height. Greatest height of wave probably occurred at approximately 700 ft from the Zeropoint.

G. Number. Near the Zeropoint there were only three waves of appreciable height; there were 6 at a range of 12,000 ft and 14 or more at a range of 22,000 ft.

H. Symmetry. Waves were not perfectly symmetric about the Zeropoint. Lack of symmetry was presumably due to asymmetry in underwater coral heads and shoals.

I. Waves on Bikini Beach. As they entered the shallow water off Bikini beach (approximately 18,500 ft from the Zeropoint) the waves travelled slower and became steeper and higher. Maximum breaker height was 15 ft.

J. Limit of Range. Waves were not detected except at Bikini Atoll.

K. Origin. The first wave was produced by the initial outward thrust of the water. Subsequent waves existing near the Zeropoint were probably caused by the collapse of the water cavity and the subsequent formation of a mound of water at the center. The fact that there were so few measurable waves near the Zeropoint shows that the amplitude of oscillations (if any) of the central region diminished rapidly with time.

L. Energy. Less than 1 percent of the energy released in the detonation went into generation of water waves.

M. Damage Produced. Waves probably made significant contributions to the damage produced on FALLON, GASCONADE, HUGHES, PENSACOLA, and SARATOGA. Some beach erosion and island flooding resulted from waves reaching Bikini Island.

N. Transport by Waves. Inner target vessels were displaced laterally by waves through distances of the order of 100 to 200 ft.

No radioactive materials were transported to beaches by the waves.

Debris was carried inland, as far as 200 ft in some cases.

28.005 Bottom Phenomena.

A bottom crater of maximum depth 25 ft was created by the explosion. The crater had a maximum diameter of 1100 yd and a minimum diameter of 600 yd. The area over which the crater depth was more than 20 ft had a maximum diameter of 700 yd and a minimum diameter of 250 yd. This area was centered at a point more than 100 yd southwest from the Zeropoint. Various minor "craters" of 5 to 10-ft depths were produced inside the main crater. (Source: Ref. 300-16)

Net amount of material removed from (and not returned to) the bottom crater region was 2, 200, 000 yd^3. Perhaps 500,000 yd^3 of material was removed and fell back into the crater.

A layer of sand and mud several feet thick was deposited on the bottom in the neighborhood of the Zeropoint.

An appreciable amount of material remained in suspension in the water for two weeks after the explosion.

28.006 Other Results.

A. Introduction. Many various results other than those discussed previously in this History were obtained in the Test. Some of the more interesting ones are presented very briefly below:

B. Temperature. Attempts to measure the average temperature rise produced in the Lagoon water in the center of the target array were unsuccessful.

C. Seismological Phenomena. Earth waves were picked up at many stations in the Pacific area and in Continental U. S. Amplitudes of the P wave as measured in Continental U. S. were of magnitude $5\frac{1}{2}$, on the earthquake scale and for an earthquake at similar range. (Source: Ref. 300-19)

Seismic vibrations had an amplitude of two millimeters and a period of 0.3 sec at Amen Island, 8 mi from the Zeropoint. The total energy in the seismic vibrations at this distance was between 10^{15} and 10^{16} ergs. (Source: Ref. 300-16)

D. Tidal Waves and Tsunamis. No tsunamis or abnormal tides were produced.

E. Magnetic Phenomena. No magnetic phenomena were detected.

F. Ionization Phenomena. No definite evidence was obtained of ionization phenomena.

G. Reflectivity and Conductivity Phenomena. No atmospheric reflectivity or conductivity phenomena were detected at great distances. Even locally no noteworth effects were found.

H. Radioactivity at Great Distance. Radioactivity in the air was detected several days later at several stations located thousands of miles away, to leeward.

I. Remote Detection. Remote detection was accomplished only by earth shock and by radioactivity in the air. See paragraph C above.

J. Winds Produced by Base Surge. Wind velocities as high as 25 knots occurred 3000 yd from the Zeropoint; they occurred several minutes after passage of the pressure wave in air, and probably represent continuation of the outward motion of the base surge.

Chapter 29

Correlation and Discussion of Test B

Outline

Chapter 29

Correlation and Discussion of Test B

29.001 Introduction.

This Chapter contains, first, general correlations and conclusions regarding the outcome of Test B, and second, various comments on the adequacy and success of the Test from a technical and technical-administrative point of view.

The correlations and conclusions are for the most part those of the JTF-1 Technical Historian. Most of them have not been approved, and it is expected that further study by experts will lead to minor changes in the correlations and conclusions. The tentative findings presented here are intended (1) to give a rough over-all picture of the outcome of the Test, and (2) to serve as a basis of discussion.

29.002 Loss of Military Efficiency of Ships.

A. Introduction. A rough but simple definition of military efficiency of a ship itself is included in Appendix III.

B. Immediate Loss. Fig. 29.1 shows the range (estimated by the JTF-1 Technical Historian) at which specified extent of immediate (i.e., first hour) loss of military efficiency of ships themselves is probable (probability equal to 50 percent). Ranges are horizontal distances from the projected Zeropoint. Estimates apply to a U. S. surface combatant vessel of unspecified type.

The following data are tentatively proposed:

Range for very serious immediate loss	700 yd
Range for serious immediate loss	900 yd
Range for moderate immediate loss	1000 yd
Range for slight immediate loss	1500 yd

C. Long Term Loss. It is not possible to make useful estimates as to the long term loss of military efficiency of ships themselves as a result of mechanical and electrical damage. Even serious loss of military efficiency from such cause may be corrected in hours or days in some cases, especially if the ship is very close to a repair yard; yet even small loss of military efficiency of the ship itself may take months to correct, if the damage is deepseated and if the ship is far from base.

Considering "contamination" damage (including contamination by plutonium) as well as mechanical and electrical damage, it is clear that ships at ranges as great as roughly 1500 yd (in an unspecified direction with respect to wind direction) may be uninhabitable for months, unless some very effective decontamination measures are taken.

D. Weakest Link. There is perhaps no outstanding "weakest link" as regards immediate loss of military efficiency from mechanical and electrical damage; hulls, turrets, miscellaneous machinery, and electrical equipment were of comparable vulnerability.

29.003 Loss of Military Efficiency of Crews.

A. Introduction. A rough but simple definition of efficiency of a crew per se is included in Appendix III.

B. Immediate Loss. Fig. 29.1 shows the range (estimated by the JTF-1 Technical Historian) at which specified extent of immediate (i.e., first hour) loss of military efficiency of crews per se would be probable (probability equal to 50 percent). (Normal 1945 shielding is assumed; also "typical" type and orientation of ship.) The tentatively proposed ranges of interest are:

Range for very serious immediate loss of efficiency	600 yd
Range for serious immediate loss of efficiency	800 yd
Range for moderate immediate loss of efficiency	1000 yd
Range for slight immediate loss of efficiency	2000 yd

C. Long Term Loss. Tentative proposals as to ranges for long term loss (of indicated severity) of military efficiency of crews per se are:

Range for very serious long term loss	2500 yd
Range for serious long term loss	2800 yd
Range for moderate long term loss	3200 yd
Range for slight long term loss	4000 yd

However, the tactical significance of these figures is questionable since it would often be possible to replace the crew within a few weeks.

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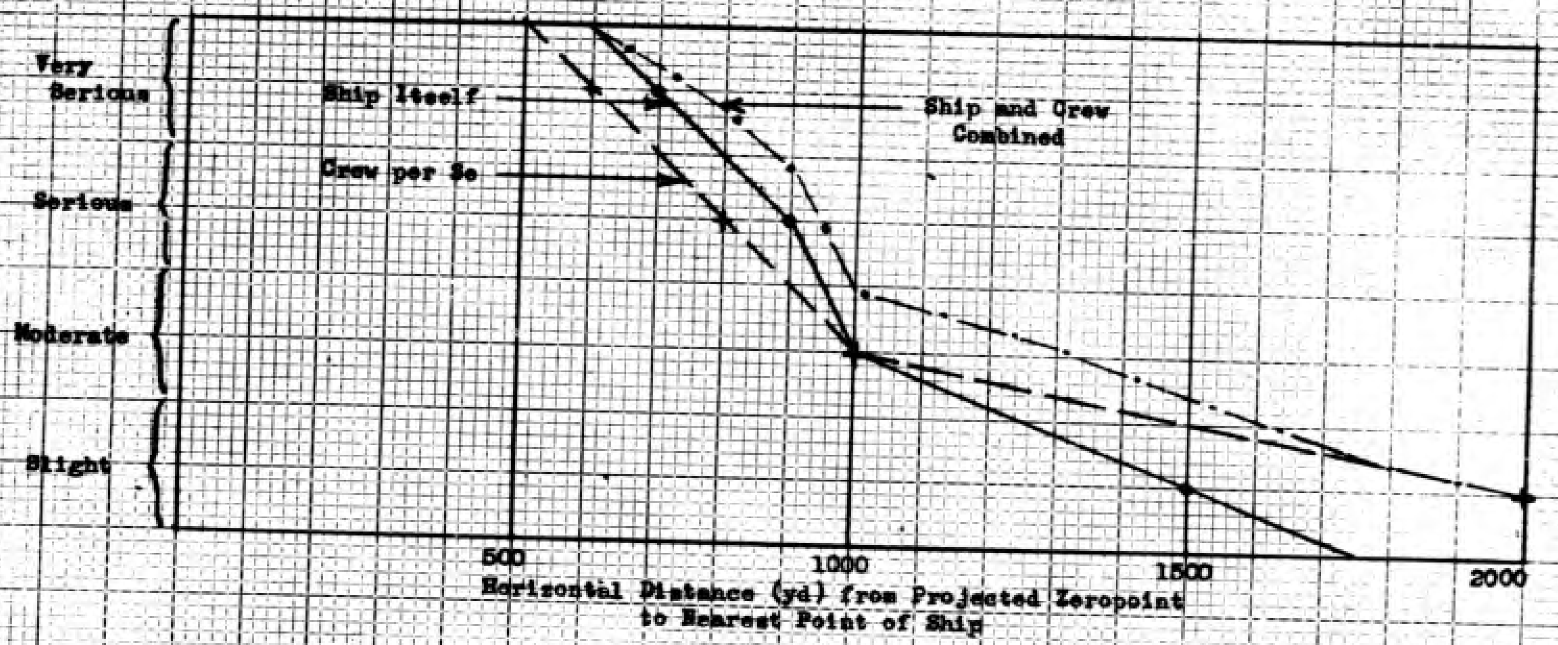

Fig. 29.1 Immediate Loss of Military Efficiency versus Range, Test B.

Source: Estimates by JTF-1 Technical Historian

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29.004 Loss of Combined Military Efficiency.

A. Introduction. For simplicity, the abbreviation CME is used below for "combined military efficiency." A rough but simple definition of combined military efficiency is included in Appendix III. The term refers, of course, to the efficiency of ship and ship's crew, considered in combination.

B. Immediate Loss. Fig. 29.1 shows the range (estimated by the JTF-1 Technical Historian) at which specified extent of immediate (i.e., first hour) loss of combined military efficiency would be probable (probability equal to 50 percent).

The tentatively proposed ranges of interest are:

Range for very serious immediate loss of CME	800 yd
Range for serious immediate loss of CME	950 yd
Range for moderate immediate loss of CME	1300 yd
Range for slight immediate loss of CME	2000 yd

C. Long Term Loss. Long term loss of combined military efficiency would be very serious for typical combatant surface vessels which are located at ranges as great as roughly 1500 yd (in an unspecified direction with respect to wind direction); unless effective decontamination measures were taken, the loss of efficiency might last for months.

29.005 Decreasing the Ranges of Loss of Military Efficiency of Ships.

No simple method suggests itself for appreciably decreasing the ranges of immediate loss of military efficiency of vessels suffering mechanical or electrical damage. Presumably thoroughgoing redesign would be required; probably any major strengthening of the vessels would entail increased weight and decreased speed.

29.006 Decreasing the Ranges of Loss of Military Efficiency of Crews.

In the search for means of decreasing the ranges or extents of immediate loss of military efficiency of crews per se the following procedures may deserve study: (1) quitting the area at full speed upwind or crosswind; (2) keeping or at least immediately bringing personnel below decks (preferably behind considerable thicknesses of steel); (3) designing superstructures so that little or no water can enter and so that practically all the water falling onto the vessel runs off immediately (i.e., eliminating undrained corners, open lifeboats, crevices, and porous materials such as rope, canvas, wood); (4) immediately stopping pumps taking water into the ship; (5) providing prompt means of washing off all exposed surfaces; (6) providing Geiger counters for determining what areas are "hot," and preventing access to such areas; (7) providing disposable shoes, gloves, coveralls, etc., for personnel who must work in "hot" areas. Measures to strengthen morale might be required also.

Of course, personnel should be taken off "hot" vessels as soon as feasible and given appropriate medical care.

29.007 Decreasing the Ranges of Loss of Combined Military Efficiency.

Perhaps the only relatively simple methods for appreciably reducing the ranges or extents of loss of combined military efficiency are the methods described in the previous sections.

29.008 Ranges of Damage or Injury Production by Causative Factors.

A. Introduction. No final analyses have been made as to relative importance of the various causative factors. However, the following tentative analysis may be of value as a basis for discussion.

B. Shock Wave in Water. Shock wave in water probably accounts for the major part of the mechanical damage produced in vessels themselves. The shock wave in water is likely to be lethal to ships within 600 yd (at which radius the peak underwater pressure is 1700 psi gage).

C. Water Waves. Water waves probably produce a small but significant fraction of the mechanical damage to surface vessels within 700 yd, at which radius the wave height from trough to crest is 45 ft.

D. Shock Wave in Air. The shock wave in air probably causes appreciable damage to vessels (and would probably cause, including primary and secondary effects, extensive injury to personnel) situated within 800 yd, at which radius the peak pressure in air is 6.6 psi gage.

E. Gamma Radiation. Gamma radiation would be the principal cause of short term and long term injury to personnel aboard target vessels within 4000 yd at Mike Hour. Topside personnel within 700 yd would receive lethal dosages (400 roentgens) within 30 sec to 1 min and would receive roughly 20 times the lethal dosage (8000 roentgens) within the first hour; personnel within 1700 yd would receive lethal dosages within 7 min, and those within 2500 yd (crosswind or downwind) would receive lethal dosages within 3 hrs.

Personnel situated below decks on well closed ships would receive only 1/2 to less than 1/10 the dosages received by topside personnel. (As indicated in Chap. 19, gamma radiation intensity is reduced to 50 percent by a 2-cm thickness of steel, and to approximately 1 percent by a 14-cm thickness of steel.)

(Note: According to some very recent analyses, the thickness of steel required to halve the intensity of gamma radiation may be considerably greater than 2 cm, and the intensity of radiation penetrating a considerable thickness of steel may be far greater than had been thought previously.)

Topside personnel within 700 yd upwind (and much greater range downwind) would suffer very serious loss of military efficiency within the first hour after Mike Hour, and even below decks personnel in the same area would suffer serious or moderate immediate loss of military efficiency. Even at 2000 yd, topside personnel would receive considerably more than the lethal dosage and would thus lose some military efficiency even within the first hour.

Personnel on vessels capable of fleeing the base surge might, of course, escape the gamma radiation and other nuclear radiation. (The base surge moves outward at the initial rate of approximately 45 knots.)

Symptoms of injury from gamma radiation are discussed in Sec. 19.008.

Principal source of the gamma radiation on target vessels is, of course, the fission products; gamma radiation is also emitted in considerable quantity by radioactive sodium produced by neutron capture. (See Sec. 27.005.) Gamma radiation emitted from the detonating bomb itself was almost entirely stopped by 25 to 50 ft of the Lagoon water and was thus of little consequence.

The time rate of decay of gamma-radioactive materials is discussed in Sec. 27.005.

F. Beta Radioactivity. Beta radioactivity is very intense on target vessels, but is of only minor importance in view of its short range (only a few yards) in air and its extremely short range (fraction of a millimeter) in solids. It would present a hazard principally only to the exposed skin of topside personnel. Beta radioactivity is produced mainly by the fission products.

G. Alpha Radioactivity. Alpha radiation from plutonium inhaled, ingested, etc., might prove fatal over a period of years. The harmfulness of the plutonium is aggravated by its tendency to accumulate in certain crucial regions of the body. Fifty to 100 micrograms may perhaps be fatal under such circumstances. Local but very dangerous concentrations of plutonium may exist on target vessels for months. Thus, inspection personnel entering target vessels long after the gamma radiation has ceased to be a menace may eventually be affected by plutonium "poisoning" unless proper precautions were taken.

H. Neutrons. Neutrons emitted from the detonating bomb were slowed down and absorbed before penetrating more than 25 or 50 ft of Lagoon water. They are of little significance except for the radioactive isotopes they produce. (See Paragraph E above.)

29.009 Technical Shortcomings of the Test.

While there were no technical shortcomings of any relative importance, these minor imperfections deserve mention: (1) the temperature rise in the Lagoon water was not measured; (2) values of gamma radiation intensity on some of the more important vessels were "off-scale" with the result that only lower limits (8000 roentgens) were established; (3) information is meager as to the rate of decay of the radioactivity during the first few hours and days, making a number of interesting "backward extrapolations" relatively inaccurate; (4) no accurate information was obtained as to the greatest distance at which downwind vessels would be seriously contaminated; (5) a few of the "black boxes" failed to operate correctly.

29.010 General Appraisal of the Test.

The Test was an entire success from the technical as well as the operational point of view. The bomb was detonated at the correct time and position; the target vessels were in (or very close to) their specified positions and they received graded damage as desired. The instrumentation program was very successful, and damage inspection was completed as promptly as radiological clearance permitted.

The very great importance of radioactive contamination by fission products was fully explored, and the insidious potentialities of plutonium contamination were brought to light. The Test was the world's fifth test of the atomic bomb, but it was the first test in which the radioactive "poisonous" material remained in the "biosphere," and thus presented a lingering and invisible menace to man and other forms of life.

A beginning was made at developing methods of decontamination; radioactive vessels were made available for continuing research and training in radiological decontamination, a field now known to be of prime importance.

Chapter 30

Comparison of Tests

Outline

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Chapter 30

Comparison of Tests

30.001 Introduction.

The two Tests were of very different type, and are therefore difficult to compare. Furthermore no final or approved comparisons have yet been made.

Comparisons presented below have in most instances been made by the JTF-1 Technical Historian, and are intended for interim use, as bases for discussion.

30.002 Comparisons.

Aspect Compared	Test A	Test B	Remarks
Altitude or depth	518 ft above surface	90 ft below surface	
Energy release	19.1 kilotons TNT	20.3 kilotons TNT	Remarkably alike; essentially the same as the values for Trinity and Nagasaki. Energy release at Hiroshima was appreciably less.
Number of vessels wholly or partly within 1000 yd	18 (4 of these were within 500 yd)	19 (6 of these were within 500 yd)	
Number of vessels sunk	5	9	This comparison is almost irrelevant as the target arrays were dissimilar.
Number of non-sunk vessels immobilized by mechanical or electrical damage.	6	5	Same comment as above.
Injury to animals	-	-	No meaningful comparison possible.

(con't.)

Aspect Compared	Test A	Test B	Remarks
Pressure in air at 1000 yd	10.5 psi gage	4.8 psi gage	As regards pressure in air, Test B was equivalent to an air burst of 4 kilotons TNT.
Optical Radiation	very intense (See Sec. 17.002)	negligible	
Period of intense gamma radiation	99 percent of dosage was delivered within the first 10 seconds (45 percent within the first second)	the greater part within the first 5 minutes but significant amounts for many days	-
Region emitting intense gamma radiation	fireball and mushroom	column, cloud, and base surge; later, contaminated vessels and Lagoon water	-
Maximum time-integrated gamma-radiation dosage topside on target vessel at 1000 yd	1800 roentgens	Approximately 10,000 roentgens	Test-B value depended greatly on wind direction.
Effect of alpha radiation	negligible at all times	would be fatal even to persons reboarding contaminated target vessels months after the explosion. (fatalities might result from ingestion, inhaling, etc., of very small quantities of plutonium, which is alpha-radioactive.	-
Effect of neutron radiation	fatal within 450 yd even to below-deck personnel.	negligible (except indirectly through formation of radio-sodium)	-

(con't.)

Aspect Compared	Test A	Test B	Remarks
Disposition of fission products	carried away in the mushroom and cloud	10 to 50 percent remain in the target area water and vessels	The very harmful gamma radioactivity decreases according to $1/T^{1.3}$ law.
Disposition of plutonium	same as above	same as above	The harmful and insidious alpha-radioactivity diminishes very little over periods of months or years.
Horizontal range at which probability is 50 percent that a surface combatant vessel itself will suffer immediate (i.e., first hour) loss of military efficiency:			
Very serious loss	900	700	In each case the greater value (Test A versus Test B) is underlined.
Serious loss	1000	900	
Moderate loss	1300	1000	
Slight loss	1500	1500	
Same, but for crews per se			
Very serious loss	700	600	
Serious loss	800	800	
Moderate loss	900	1000	
Slight loss	1000	2000	
Same, but for vessels and crews in combination			
Very serious loss	900	800	
Serious loss	1020	950	
Moderate loss	1300	1300	
Slight loss	1500	2000	

(con't.)

Aspect Compared	Test A	Test B	Results
Same, but for long term effect on crews per se			
Very serious loss	800	2500	
Serious loss	1100	2800	
Moderate loss	1400	3200	
Slight loss	1700	4000	
Phenomena detectable at distances of thousands of miles	radioactivity in the air	earth shock and perhaps radioactivity in the air.	
Principal cause of immediate loss of military efficiency of vessels themselves.	shock wave in air	shock wave in water	-
Same but re crews per se.	within 550 yd, neutron radiation or drowning; within the annulus from 550 to 900 yd, gamma radiation; outside 900 yd, optical radiation and shock wave in air.	gamma radiation (at all ranges)	-
Same but re long term effects on crews per se.	same as above, except that gamma radiation is important even beyond 900 yd.	same as above	
Principal source of danger to persons boarding target vessels one month after Mike Hour.	fission products	fission products and plutonium	-

(con't.)

Aspect Compared	Test A	Test B	Remarks
Period in which Lagoon was dangerously contaminated	Less than one hour.	one to two weeks	Lagoon water "changes" in 1 or 2 months.
Period in which target vessels were appreciably contaminated	Less than one day, ordinarily	weeks of months	In Test B, the period can be very greatly shortened by decontamination measures.

Chapter 31

Termination of Operation

Outline

Chapter 31

Termination of Operation

31.001 Introduction.

On 10 Aug 46 Commander JTF-1 departed from Bikini. After conferring with CinCPac at Pearl Harbor, he hauled down his flag on 18 Aug 46 from the MT MCKINLEY and departed by air for Washington, D. C. Command of Joint Task Force One activities in the Pacific now passed to Rear Adm. Fahrion, who had the titles Commander Naval Task Groups, JTF-1, and Commander Advance Echelon, JTF-1. On 26 Aug 46 the administration of JTF-1 activities shifted to Washington, D. C.

On 7 Sept 46, the President announced the indefinite postponement of Test C. On 9 Sept 46 Commander JTF-1 formally terminated preparations for Test C and directed that Operation Crossroads be terminated as soon as practicable.

In accordance with directives from the Joint Chiefs of Staff, Joint Task Force One was formally dissolved on 1 Nov 46. To complete the preparation of reports and summarization of technical data, a Joint Crossroads Committee was established at that time.

31.002 Disposition of Target Vessels.

Twelve out of the thirteen ships sunk as a direct result of the two atomic bomb explosions were not salvaged. The SKIPJACK was brought to the surface on 2 Sept 46.

The HUGHES and the FALLON were beached (on 26 July 46 and 27 July 46, respectively) at Enyu Island to keep them from sinking. DENTUDA was beached at Enyu on 28 July 46. All three were later salvaged. The capsized LCT-1114 was sunk by demolition charges on 30 July 46. ARDC-13 sank on 6 Aug 46 from progressive flooding. LCI-620, damaged by prolonged beaching not directly attributable to either Test A or B, was towed to sea and sunk by gunfire on 10 Aug 46; LST-125 was similarly sunk 14 Aug 46; LCT's 1132 and 1415, although not target vessels, were in condition similar to LCI-620, and were sunk by gunfire near Rongelap 15 Aug 46. Five target vessel LCT's, 414, 812, 1175, 1187, 1237, and LCT-1268 (non-target vessel), in Bikini Lagoon were sunk by demolition charges.

Since dangerous radioactivity persisted aboard the most heavily contaminated target vessels and impeded salvage, movement, and assessment of damage, the decision was made that these ships be decommissioned at Kwajalein. ComNavTaskGroups was ordered on 16 Aug 46 to shift base to Kwajalein and proceed with the decommissioning of specified ships. This movement to Kwajalein was completed early in September.

The CONYNGHAM, TUNA, DENTUDA, PARCHE, SEARAVEN, and SKATE proceeded from Kwajalein to Pearl Harbor, arriving there on 6 Sept 46; the SKIPJACK was towed to Pearl Harbor, arriving there on 22 Sept 46. These ships were then moved to the San Francisco area for decommissioning and for radiological study.

The remainder of the target vessels were anchored at Kwajalein. Included were: 3 battleships, 2 U. S. cruisers, 1 ex-German heavy cruiser, 1 carrier, 10 destroyers, 12 merchant type ships, 5 LST's, 2 LCI's, 8 LCT's, and 1 YOG.

Plans were made to tow GASCONADE, INDEPENDENCE, FALLON, and CRITTENDEN to San Francisco, to tow HUGHES, PENSACOLA, and SALT LAKE CITY to Bremerton, and NEW YORK and NEVADA to Pearl Harbor -- for detailed structural and radiological examination.

<u>31.003 Disposition of Non-Target Vessels.</u>

The Drone Carrier Unit, Press and Observers Unit, ALBEMARLE, FURSE, BOUNTIFUL, and CUMBERLAND SOUND had sailed from Bikini by 1 Aug 46.

Photographic Carrier Unit, Surface Patrol Group, Drone Boat Unit, BURLESON with all surviving test animals, four PGM's, BAYFIELD, APPLING, two LST's with Army equipment and personnel from Kwajalein and Eniwetok, OTTAWA and ST CROIX with SeeBee equipment, BOTTINEAU and the Army Group had sailed by 10 Aug 46.

Remaining after 10 Aug 46 were: Target Group, Service Group, Seaplane Unit, part of the Transport Unit, HAVEN, and WHARTON.

By 26 Sept 46 all vessels had left Bikini.

The majority of the non-target vessels were transferred from Commander JTF-1 to their prior commands.

31.004 Other Final Activities.

A. Radiological Safety School. On 5 Aug 46 Commander JTF-1 requested the establishing of an emergency radiological safety training program. The scope of the program was later enlarged to train officers themselves capable of forming radiological safety groups within the various services. One important object of the program was to assist in the decontamination and radiological clearance of non-target vessels contaminated in Test B. Another object was to assist in the decontamination research program proposed by BuShips.

Captain G. M. Lyon, (Navy) the JTF-1 Safety Adviser, was requested by Commander JTF-1 to initiate the training program and to act as Director of Training. The Safety Adviser appointed an Officer in Charge of the school, a Training Officer, and an Assistant Training Officer. First plans were drafted on 8 Aug 46; later these plans were outlined in great detail.

On 28 Aug 46 this group arrived in Washington, D. C. and began organization of the school. The first class began 9 Sept 46 at the Navy Department, Washington, D. C.

Students included officers from the Army Air and Ground Forces, Navy, Marine Corps, and U. S. Public Health Service. The training program included a four-week academic course in Washington, D. C., and three months of practical instruction in radiological safety in the field.

B. Joint Crossroads Committee. Following the dissolution of JTF-1 1 Nov 46, the Joint Chiefs of Staff authorized the formation of the Joint Crossroads Committee: "The Joint Crossroads Committee, as an agency of the Joint Chiefs of Staff, will supervise the completion of final supplementary technical reports of Operation Crossroads, the consolidation and dissemination of reports, and the performance of such other duties in connection with the atomic bomb tests as may be directed by the Joint Chiefs of Staff."

The four members comprising the Committee are: Rear Adm. W. S. Parsons (Chairman), Rear Adm. T. A. Solberg, Brig. Gen. T. S. Power, and Col. D. H. Blakelock; Capt. H. R. Carson (Navy) is Executive Secretary.

The Technical Assistants are: Capt. F. L. Ashworth (Navy) and Capt. Horacio Rivero, Jr. (Navy).

The Scientific Consulting Board consists of: Dr. R. A. Sawyer, Dr. N. E. Bradbury, Dr. John von Neumann, Capt. G. M. Lyon (Navy), and Col. S. L. Warren.

The Divisions of the Committee are as follows: Executive Secretary's Division, headed by Capt. H. R. Carson (Navy); Technical Director's Division, headed by Dr. E. S. Gilfillan; Director of Ship Material Division, headed by Rear Adm. T. A. Solberg; Radiological Safety Division, headed by Col. A. A. deLorimier; and Crossroads Documents Division, headed by Dr. W. A. Shurcliff.

C. Radiological Clearance of Target and Non-Target Vessels. On 24 Sept 46 BuShips and BuMandS assumed responsibility for giving final radiological clearance to vessels and prescribed detailed decontamination and clearance procedures for vessels destined to join the active fleet. For ships destined for inactivation or disposal, additional procedures were established.

31.005 Status of Bikini Atoll.

After Test B, and to the extent that radiological conditions permitted, the Survey Unit (Task Group 1.8.5) made further hydrographic surveys, installed navigational aids, and conducted land surveys, all in anticipation of Test C. The Construction Unit continued preparations (begun earlier in the operation) of moorings for the Test-C target vessels; it began construction for instrument towers, blasted out coral heads, and prepared landings at the western islands.

However, following the Presidential announcement that Test C was indefinitely postponed, all survey and construction activities at Bikini Atoll were brought to a close; the Atoll was completely evacuated on 26 Sept 46.

Chief of Naval Operations ordered that surveillance of this area be continued to restrict entry of foreign, merchant, or private shipping which had not been duly authorized.

31.006 Preparation of Reports.

Among the various kinds of reports prepared on the results of the Operation, were these: (a) group reports, by individual groups within the Task Force, (b) Operational Report on the Operation as a military activity, (c) Top Secret Technical Report covering all phases of the Operation but stressing the technical activities and results, (d) Official Pictorial History of Operation Crossroads, and (e) Official Report for the public. These are considered separately below:

A. Group Reports. By Group Reports is meant all individual reports prepared by individual groups (technical and nontechnical) within JTF-1. Some of these reports were prepared by order of higher authority; others were prepared on the initiative of the group itself. Some were prepared as more or less unique monographs; others comprised regular weekly or monthly series. Some were prepared by the group leaders themselves; others were prepared by specially designated group historians or group reporters.

Some of the more important of the technical reports are listed in the Bibliography attached to this Technical Report.

B. Operational Report. The formal Operational Report of Operation Crossroads as a military activity was prepared by Capt. A. B. Leggett under the direction of the Chief of Staff. This Report, which does not attempt to cover the technical phases of the Operation, was completed in mid-November 1946, and contains over 1000 pages.

C. Technical Report. The Top Secret Technical Report on Operation Crossroads was prepared under the general guidance of R. Adm. W. S. Parsons, Deputy Task Force Commander for Technical Direction.

This Report is the principal over-all summarizing technical report by Commander JTF-1. It is intended for a study by the Joint Chiefs of Staff, by the Evaluation Board, and by other authorized groups.

Preparation of the Report was the immediate responsibility of Dr. W. A. Shurcliff, Technical Historian of JTF-1. He was assisted by Mr. D. Z. Beckler (Deputy Historian), Mr. Peregrine White (Assistant Historian), Mrs. Virginia Shapley, Editor-in-Chief, and by others.

D. Pictorial History. On 10 July 46 the Commander JTF-1 decided that a pictorial history should be prepared partly for general value to the public and partly as a souvenir book for the men who helped in the carrying out of the Operation. This album was to be nontechnical, and was to emphasize the general operational and work-a-day phases of preparing and executing the Operation.

On 31 July 46 responsibility for preparing this pictorial history was given to the JTF-1 Historian; Mr. Peregrine White, Assistant Historian, was named as Editor.

The pictorial history, later named "Official Pictorial History of Operation Crossroads," is being published by the William H. Wise and Co. and has a sale price of approximately $1.65 in Ships Stores and $2.00 at commercial bookstores.

E. Official Report for the Public. The decision was made on 29 Jan 46 by Commander JTF-1 that considerable effort should be made to prepare a textual report for the public on the outcome of the tests. The report was to contain all appreciable technical results which -- in the light of security regulations established by the Joint Chiefs of Staff -- might be released.

Dr. W. A. Shurcliff, JTF-1 Historian, was given the responsibility for preparing this Report.

The manuscript is expected to be practically completed by 1 Jan 47, and the book is expected to be placed on public sale by the Spring of 1947.

F. Motion Picture Films. A number of motion pictures have been made or are being made for showing to technical and nontechnical groups. Some of these films have already been circulated.

Chapter 32

Test-C Prospects

Outline

Chapter 32

Test-C Prospects

32.001 Introduction.

Although Test C, the deep underwater explosion was indefinitely postponed by President Truman on 7 Sept 46, the various pros and cons of eventually holding such a test are still of considerable interest.

The arguments favoring eventually holding a deep-underwater test are these:

A. Although we now have good information as to what happens when an atomic bomb goes off in air or slightly beneath the surface of the water, we have no clear idea as to what the results would be of detonating an atomic bomb at great depth beneath the surface of the ocean. We have no means of estimating the effects with high accuracy. Conceivably the effects might be significantly greater than expected and might provide data of great military and scientific value.

B. According to some sections of the public, the underwater test would "obviously" be the one which would be most damaging to naval vessels; it would "obviously" be the crucial test, re survival of navies; that test is the one the Navy "obviously fears."

C. The underwater test would show how well the atomic bomb would serve to intercept a hostile fleet approaching our country.

D. Only after we have studied a deep-underwater explosion will we be able to interpolate accurately, as in predicting the effects of an explosion at any arbitrary intermediate depth.

E. Some advance preparations have already been made for Test C.

The arguments against holding such a test are these:

A. There is no firm reason for believing that a deep underwater explosion would do more damage than a surface explosion or an explosion at or immediately below the surface; shock effects might not prove to be as overwhelming as some persons expect, and many important atomic-bomb effects would be almost entirely eliminated -- that is, optical radiation, neutron and gamma-ray radiation, would be almost entirely absent.

B. Concentrations of naval vessels are usually to be found in harbors; but harbors are ordinarily relatively shallow; therefore the deep-underwater test would be irrelevant to principal naval targets (i.e., to the commonest concentrations of naval vessels).

C. Even many important ocean areas are very shallow, e.g., the North Sea and the Atlantic Shelf area.

D. Even though in the past there have been many naval vessel concentrations in open (deep) ocean, it would be an obvious and simple matter for future fleet commanders to space their ships very widely -- as widely as would be required so that not more than one or two vessels would be put out of commission by one atomic bomb.

E. It would presumably be possible for an enemy in advance of outbreak of war to plant atomic bombs in harbors; and it is conceivable that he would be able to pre-train, say, his V-2 type atomic bomb carriers on our harbors; but no such advance preparations or automatic bull's-eyes would be possible for a deep underwater bomb - i.e., a bomb to be used against a fleet moving in open ocean.

F. Even if an enemy could make bombs usable at great depth he might find it difficult to dispatch the bombs quickly to the particular, deep-underwater spot selected. Entirely new techniques and operational procedures would be needed. (If delivery were not made quickly, the target fleet would have time to change course and disperse. If delivery were made by airplane, it is very possible that the airplane would be intercepted and shot down. If delivery were made by submarine, it is quite possible that the submarine would be intercepted and sunk.)

G. An atomic bomb designed for use at great depths would probably be a special-purpose weapon tactically usable only in deep ocean waters. On the other hand an air-burst bomb would be usable the world over -- i.e., over cities, armies, harbors, or fleets at sea, and a heavy-impact atomic bomb for delivery by aircraft for underground or underwater detonation would have broad application, particularly for attacking military or industrial concentrations immediately adjacent to bodies of water.

H. Funds and personnel may continue to be scarce.

32.002 Status of Specifications of Test.

Opinion among principal technical personnel of JTF-1 is to the effect that if a Test C is eventually held, it should conform to these principal specifications:

Depth of bomb:	1000 to 2000 ft.*
Depth of bottom:	At least 2.5 times the depth of bomb.
Number of target vessels:	Few (or none). By obtaining complete data on pressure, the damage which vessels would suffer could be computed with fair accuracy merely from the damage data obtained in Test B.
Number of instruments:	Relatively few; emphasis should be placed on a few well proven instruments very carefully placed, rather than on a great many instruments of uncertain performance placed informally.

(Source: Ref. 300-5; 300-25; 300-26)

33.003 Indefinite Postponement.

On 7 Sept 46, acting with the advice of the Joint Chiefs of Staff, President Truman postponed the Test indefinitely. His statement was as follows:

> "In view of the successful completion of the first two atomic bomb tests of Operation Crossroads and the information derived therefrom, the Joint Chiefs of Staff have concluded that the third explosion, Test C, should not be conducted in the near future...
>
> "The additional information of value expected to result from Test C is such that the Joint Chiefs of Staff do not feel that completion of this test in the near future is justified."

---

* By using a depth in the neighborhood of 2000 ft., the troublesome radioactive plume and cloud would be avoided.

APPENDIX I

CALENDAR OF EVENTS

1. Introduction.

A full chronology of "atomic energy" events prior to 1946 is contained in "Report No. 1211 to Accompany Bill 1717, 79th Congress, 2nd Session."

A complete chronology of Queen Day, A-Day, William Day, and B-Day is contained in "Operational Report of JTF-1" by Captain A. B. Leggett (Navy).

The chronology presented below is brief, listing only events of major interest.

All dates and times are local at places concerned unless specified otherwise.

2. Brief Chronology.

Date	Month	Year	
	Jan	1939	The discovery by German scientists of fission of uranium was announced.
6	Dec	41	Decision was made by Dr. Vannevar Bush, Director of the Office of Scientific Research and Development, to undertake an "all-out" effort for the development of atomic bombs for use in World War II.
13	Aug	42	Manhattan Engineer District was established to develop atomic bombs.
2	Dec	42	First self-sustaining nuclear chain reaction was achieved at Chicago.
		1944	Manhattan Engineer District considered using atomic bomb against Japanese fleet at Truk Island.
16	July	45	First atomic bomb was detonated, at Alamogordo, New Mexico. Exact time of detonation was as follows:

Date	Month	Year	(con't)	
			Place	**Time of Detonation**
			Alamogordo, N. M. (MWT)	16 July 0530
			Washington, D. C. (EWT)	16 July 0730
			Greenwich, England (GCT)	16 July 1130
5	Aug (GCT)	45	Second atomic bomb was detonated, at Hiroshima, Japan. Exact time of detonation was as follows:	
			Place	**Time of Detonation**
			Hiroshima, Japan	6 August 0815
			Washington, D. C. (EWT)	5 August 1915
			Greenwich, England (GCT)	5 August 2315
9	Aug (GCT)	45	Third atomic bomb was detonated, at Nagasaki, Japan. Exact time of detonation was as follows:	
			Place	**Time of Detonation**
			Nagasaki, Japan	9 August 1058
			Washington, D. C. (EWT)	8 August 2158
			Greenwich, England (GCT)	9 August 0158
25	Aug	45	Senator Brien McMahon recommended testing atomic bombs on captured Japanese warships.	
28	Sept	45	General H. H. Arnold recommended to the Joint Chiefs of Staff the atomic bombing of captured Japanese naval vessels.	
16	Oct	45	Admiral E. J. King recommended inclusion of a few U. S. Naval vessels of modern design in the target array.	
10	Dec	45	Plans for the atomic bombing of naval vessels were announced formally.	
11	Jan	46	JTF-1 was created and Vice Admiral W. H. P. Blandy was designated Commander.	
21	Jan	46	Bikini Atoll was selected as site.	
7	Mar	46	Natives were evacuated from Bikini.	
22	Mar	46	President Truman directed postponement of the Tests for approximately six weeks.	

Date	Month	Year	(con't)
28	Mar	46	Evaluation Board membership was announced.
30	Mar	46	Presidents Evaluation Commission membership was announced.
15	May	46	Commander Joint Task Force ONE hoisted flag on MT. MCKINLEY.
14	June	46	Revised House Joint Resolution 307, authorizing use of certain naval vessels as targets, was signed by the President.
24	June	46	QUEEN Day (Rehearsal for A-Day)
1	July	46	A-Day.
	0555		Bomb carrying plane became airborne.
	0603		Evacuation of Lagoon was completed.
	0850		Bomb-carrying plane started final run.
	0900 (Approx.)		Bomb was released.
	0901 (Approx.)		Bomb was detonated. Exact detonation time (MIKE Hour) was as follows:

Place		Time of Detonation
Bikini	1 July	34 sec (±5 sec) after 0900
Washington, D.C.	30 June(EST)	34 sec (±5 sec) after 1700
Greenwich, England	30 June(GCT)	34 sec (±5 sec) after 2200

	1430		Lagoon declared safe for re-entry of all ships.
	2356		Commander JTF-1 announced the sinking of CARLISLE, GILLIAM, LAMSON, and ANDERSON.
2	July	46	SAKAWA sank.
19	July	46	WILLIAM DAY (Rehearsal for B-Day).
25	July	46	B-Day.

Date	Month	Year	(con't)
	0435		Evacuation of target vessels was completed.
	0620		Evacuation of Lagoon was completed.
	0835		Bomb was detonated. Exact detonation time (MIKE Hour) was as follows:

Place		Time of Detonation
Bikini	25 July	59.7 sec (±.1 sec) after 0834
Washington, D.C.	24 July (EST)	59.7 sec (±.1 sec) after 1634
Greenwich, England	24 July (GCT)	59.7 sec (±.1 sec) after 2134

Date	Month	Year	
	2311		Commander JTF-1 announced the sinking of LSM-60, SARATOGA, ARKANSAS, YO-160, and LCT-1114. (LCT-1114 was later found capsized and adrift.)
26	July	46	PILOTFISH, SKIPJACK, and APOGON were believed to have sunk, and later these submarines were so listed.
29-30	July	46	NAGATO sank during the night.
10	Aug	46	Commander JTF-1 departed Bikini aboard MT. MCKINLEY.
19	Aug	46	Commander JTF-1 hauled down his flag on MT. MCKINLEY at Pearl Harbor and departed for Washington, D. C.
1	Nov	46	Joint Task Force ONE officially dissolved and Crossroads Board established.

Top Secret

Appendix II

Evaluation Board's List of Information Desired

Section 1. Introduction.

On 8 Aug 46 the Evaluation Board submitted to the Historian's Office a list of information desired. Some of the information desired consists merely of straightforward results of the Tests; other types of information desired consist of information already available in the technical literature and of present interest as bases of comparison or general reference; other types of information desired are more in the nature of predictions, extrapolations, and generalizations which -- at this time, at least -- can be little better than guesses.

This History attempts to include only objectively measured data, simple interpolations, straightforward generalizations, and reference to standard technology already recorded and accepted in the literature.

It is believed that predictions, extrapolations, and generalizations of debatable validity are outside the scope of this History, and should be handled by separate inquiries directed by the Evaluation Board or others, to recognized authorities.

The Evaluation Board's List of Information Desired is presented below, together with comments as to where the information in question may be found.

Section 2. Evaluation Board's List of Information Desired.

Tests in General

Information desired	Comment
1. For each test, one accurate chart showing the outlines of the ships to scale at their best-estimated locations relative to the bomb burst.	See Charts of Chaps. 10 and 20.
2. A table of critical radiological dosages for humans and species of animals used	For persons, the lethal dosages are: Gamma rays: 400 roentgens

in the test, showing variation with the character of the rays.	Slow neutrons: 5 X 10^{11} neutrons per cm^2 Fast neutrons: 1 X 10^{11} neutrons per cm^2
3. A summary of data obtained from observations of animals, including location, shielding effects, and variations from theoretical predictions.	No full analysis available in the office of the Director of Ship Material on 1 Nov 46. See, however, Chap. 15, 19, 25, and 29 for fragmentary comments.

Test A

Re Blast:

4. Composite curves (from all types of data) of blast pressure, impulse, etc., versus distance from the burst.	See Table of Sec. 16.002.
5. Best estimate of ranges at which radar gear and critical radio gear of present design would be put out of action.	See Secs. 13.009, 13.011, and 14.003.
6. Ditto on boiler casings (with steam up).	See Sec. 13.006 and Table 13.1.
7. Ditto on any other damage which would hamper operation of ships.	See Chaps. 13 and 19.
8. Composite curves of repair time required on various types of ships versus distance from the burst.	No curves were available in the office of Director of Ship Material on 1 Nov 46.
9. Best estimate of maximum ranges at which various types of ships would be sunk.	See Chap. 13 for fragmentary answer. No battleships, aircraft carriers, submarines, or U. S. cruisers were sunk.
10. Selected curves of pressure versus time at significant distances.	See Sec. 16.005.

11.	Best estimate of ranges at which unprotected personnel would be killed or incapacitated by blast.	See Chap. 19.

Re Heat and Light:

12.	Best estimate of ranges at which exposed flesh would be burned.	No animals died from flash-burns. Second degree burns occurred on exposed skin at 650 yd, and a few first degree burns as far out as 3000 yd.
13.	Ditto for flesh protected by ointment.	Such protection was excellent beyond 600 yd.
14.	Curves of maximum surface temperature versus distance from burst, for various surfaces.	Values depend on surface thickness, orientation, reflectivity, conductivity, specific heat, and evaporability. No useful data available. See Chap. 14.
15.	Curve of heat-ray intensity versus distance.	No analysis had been made by the office of the Technical Director by 1 Nov 46.
16.	Curve of ultra-violet intensity versus distance.	No data.
17.	Spectrum of the fireball and the intensity distribution therein.	Only limited data available. See Sec. 17.002. Paragraphs B and F, and Sec. 17.003.

Re Initial Flash of Gamma Radiation and Neutrons:

18.	Curves of intensity versus distance from burst.	See Sec. 17.004, 17.005.
19.	Absorption of steel, wood, air, water, brick, concrete, earth, etc. in convenient form to apply to intensity curve.	No data included in this Report.
20.	Range at which direct exposure is lethal to humans.	1350 yd (for gamma radiation) 450 yd (for neutrons)

21.	Curves showing thicknesses of steel, wood, water, brick, etc. necessary to shield humans at various distances.	No comprehensive data included in this Report. See, however, Sec. 29.008, Paragraph E re shielding by steel.

<u>Re Residual Radioactivity:</u>

22.	Chart of Lagoon showing distribution on ships and in water.	Radioactivity was negligible. See Sec. 17.009 and 17.010.

<u>Test B</u>

<u>Re Underwater Shock:</u>

23.	Composite curve (from all data) of peak pressure, impulse, etc., versus distance from the burst. If significantly different, estimated curves for different water depths.	See Sec. 26.002.
24.	Best estimate of ranges at which various types of ship or submarine hulls would be ruptured.	See Table 23.1 and Sec. 29.002.
25.	<u>Ditto</u> for internal shock damage to put ships out of action.	Same as above.
26.	Composite of curves of repair time required on various types of ships versus time at significant distances.	No data were available in the office of the Director of Ship Material on 1 Nov 46.
27.	Data on air-blast as for Test A.	See Sec. 26.006.

<u>Re Surface Waves:</u>

28.	Height, length, and maximum slope of waves versus distance from the burst.	See Sec. 26.004.

29.	Best estimate of ranges at which various types of ships at various relative headings would be swamped or capsized.	No data. See, however, Sec. 28.004, Paragraph M.
30.	Curves of maximum roll or pitch for various types of ships at various relative headings, versus distance.	Few data available. LCT-1114 at 483 yd capsized; the burst was off her starboard bow. BRISCOE, at 878 yd, rolled 14 degrees. Other non-sunk ships rolled less than 10 degrees.
31.	Best estimates of volumes of water descending from the water column or cloud at various distances from the burst. (In pounds of water per square foot.)	See Sec. 28.001, Paragraph C.

<u>Re Radioactivity and Plutonium Contamination:</u>

32.	(a) Best estimate of quantity of plutonium remaining in water, and (b) the volume of water this will contaminate at maximum lethal dilution.	Re (a): Absolute value is "Manhattan Secret;" relative value is: 10 to 50 percent of all plutonium existing after the detonation. Re (b): Lethality depends on amount taken into body; 50 to 100 micrograms might eventually cause death. Amount in body, not concentration in Lagoon water, is the crucial parameter.
33.	Best estimate of radioactive intensity distribution in the water immediately after the burst, and radioactive decay curve.	See Sec. 27.005 and 27.006.
34.	Curve of maximum volume of contaminated water versus time after explosion.	Neglecting the very slight contamination downwind outside the Lagoon, the volume of water contaminated was: B-Day 0.05 mi^3 1 Day after B-Day 0.8 mi^3 5 Days after B-Day 4.7 mi^3 (Note: Total volume of water in Lagoon is roughly 6 mi^3.)

35.	Critical exposure times (to get lethal radiological dosage) versus distance from burst.	Values range from 30 sec to 3 hr for topside personnel on vessels engulfed by the base surge. See Sec. 29.008, Paragraph E.
36.	Influence of wind, waves, and water current in dispersing contaminated water.	Radioactivity in the water became ganeral throughout the Lagoon within a week. The Lagoon water "half-changes" in 25 days.
37.	Selected radioactive decay curves on various target ships.	See Sec. 27.005.
38.	Selected curves showing intensity of emanations versus distance from contaminated ships.	A small boat roughly 100 yd from a "hot" ship received only negligible gamma radiation from that ship.
39.	Selected curves of beta-ray intensity versus distance from contaminated deck.	The beta radiation had a range of 1 or 2 meters in air.
40.	Selected beta-ray decay curves.	During the first two days, the beta radiation decay rate was greater than the gamma radiation decay rate; in the following days and weeks the decay rates became nearly identical and approached the $1/T^{1.3}$ rate discussed in Sec. 27.005.

APPENDIX III

BASIS OF COMPUTING LOSS OF COMBINED MILITARY EFFICIENCY

1. Introduction.

In the following discussion regarding a definition of combined military efficiency (CME), the following more basic definitions are employed: The military efficiency of a damaged ship is the reciprocal of the number of identically-damaged ships equal in military efficiency to one sound ship. The military efficiency of a ship's (injured) crew is the reciprocal of the number of identically-injured crews equal in military efficiency to one sound crew.

The basis presented below for computing the loss of combined military efficiency, called "Loss of CME", rests on these assumptions:

1. The loss of military efficiency of the ship is known. (This efficiency may be called "X".)
2. The loss of military efficiency of the crew is known. (This efficiency may be called "Y".)
3. Each "unit" of military efficiency of the ship depends equally on presence of effective men.
4. It is "half true" that any given man can be transferred to doing any other man's job in an emergency.
5. The fact that there are (prior to Mike Hour) surplus men is just counterbalanced by delays and unbalance in reallocating survivers among the battle stations.

2. Basis.

The computing of the loss of CME is based on these arbitrary rules:

1. If X exceeds Y (i.e., if crew shortage is most critical), the loss of CME is the average of (1-XY) and (1-Y).
2. If Y exceeds X (i.e., if the most serious loss of military efficiency is to the ship), the loss of CME is the average of (1-XY) and (1-X).

These two rules reduce to this one:

Loss of CME $= \frac{2 - S - LS}{2}$, where S is the smaller of the two quantities, X and Y, and L is the larger.

Examples:

The loss of CME for various assumed values of S and L are as follows:

L (percent)	S (percent)	Loss of CME (percent)
100	100	0
80	80	28
60	60	52
40	40	72
20	20	88
0	0	100
100	80	20
100	60	40
100	40	60
100	20	80
100	0	100
80	60	46
80	40	64
80	20	82
60	40	68
60	20	84
40	20	86

APPENDIX IV

BIBLIOGRAPHY

1. Introduction.

This Section lists reports, books, etc., of interest to persons studying Operation Crossroads. Particular emphasis has been given to technical reports.

References are listed numerically, according to the arbitrarily assigned reference numbers.

Numbers are grouped in these series:

100 Series..........Not used.
200 Series..........JTF-1 General.
300 Series..........Reports by 013, i.e., by the Technical Director and persons responsible to him.
400 Series..........Reports by 014, i.e., by the Director of Ship Material and persons responsible to him.
500 Series..........Other Crossroads reports
600 Series..........Other reports

Within each series the references are arranged more or less according to importance, the more important references being listed first.

2. References of the 200 Series.

Below are listed references by -- or applicable to -- JTF-1 in general.

Ref. No.	Date	Group	Author	Title
201	15 April 46	JTF-1	Chief of Staff	Operation Plan No. 1-46
210		JTF-1	Leggett, Capt. A. B. (Navy)	Operational Report on Operation Crossroads
220	18 Nov 46	JTF-1	Shurcliff, Dr. W. A.	Technical Report on Operation Crossroads

3. References of the 300 Series.

Below are listed references by the Office of the Technical Director (013), or by groups responsible to him:

Ref. No.	Date	Group	Author	Title
300	none	013	Sawyer, Dr. R. A.	Technical Director's Final Report.
300-1	"	"	-	List of Enclosures.
300-2	"	"	-	Introduction.
300-3	"	"	-	Highlights of Coordinator's Reports (later withdrawn, See 300-7).
300-4	"	"	-	Equivalent Energy Tonnage.
300-5	"	"	-	Test C.
300-6	"	"	-	Conclusion.
300-7	"	"	Sawyer, Dr. R. A.	Survey of Results.
300-8	"	"	Gilfillan, Dr. E. S., Jr.	Untitled paper on probable effects of A-Day nuclear radiations on crews.
300-11	"	"	Debenham, J. K. and Archer, H. M.	Report of Determination of Burst Height, Test A. Encl. A.
300-12	18 Oct 46	"	Archer, H. M.	Determination of Ship and Burst Locations for Test A and B.
300-13	27 Sept 46	"	Penney, Dr. W. G.	Air Blast and Water Shock in Tests A and B.

Ref. No.	Date	Group	Author	Title
300-14	31 July 46	013	Gerlach, Comdr. C. H.	Report on Ships Instrumentation Other than Air Blast and Underneath Pressure; Encl. C, Part 2.
300-15	7 Sept 46	"	Penney, Dr. W. G.	Reasons for Expecting Peak Pressure to Fall Off with the Radius Faster than R^{-1}; Encl. D.
300-16	7 Aug 46	"	Revelle, Comdr. Roger	Coordinator's Report on Oceanographic Work at Bikini and Surrounding Areas; Encl. E.
300-17		"	Thatcher, Dr. E. W.	Summary Report on Electromagnetic Propagation; Encl. F.
300-18	30 Sept 46	"	Hulburt, Dr. E. O.	Summary of Radiometry Measurements of Atomic Bomb Tests at Bikini in July 46; Encl. G.
300-19	27 Sept 46	"	Vaux, Comdr. George	Preliminary Evaluations of Remote Measurements of Tests A and B.
300-20	25 Sept 46	"	Warren, Col. S. L.	Nuclear Radiation Effects in Tests A and B, Preliminary Report of.
300-22	1 Sept 46	"	Hirschfelder, J. O. and Magee, J. L.	A critical Summary of Some A-Shot Measurements.
300-23	30 Sept 46	"	Holloway, Dr. M. G.	Summary of Project Y Crossroads Activities

Ref. No.	Date	Group	Author	Title
300-24		013	Gilfillan, Dr. E. S., Jr.	Time Interval Between Arrival of Primary and Reflected Shock Wave (Milliseconds). (one page chart.)
300-25		"	Penney, Dr. W. G.	Depth for Test C.
300-26	15 Oct 46	"	Von Neumann, Dr. John	Comments concerning Dr. W. G. Penney's Memorandum, "Depth for Test C."
300-27	(Same as 300-16)			
301		"	Wyckoff, C. W. and Shafton, Comdr. K.	Combined Projects, Test B, II-11, IX-16, Parts I and II.
302	30 Oct 46	013B	Revelle, Comdr. Roger	Some Rough Calculations Concerning the Amount of Water in the Column. JTF-1/013B/ms; Serial 65 (013B).
303	23 July 46	013E	Warren, Col. S. L.	Results of Radioactivity Measurements of Test, Preliminary Report.
310	13 Nov 46	013E	Scoville, Dr. H. P.	Memorandum entitled "Time of Onset of the Effects from Radiation Exposure."

4. References of the 400 Series.

Below are listed references by the Director of Ship Material, or by groups responsible to him.

Ref No.	Date	Group	Author	Title
410	4 Aug 46	014	Solberg, Rear Adm. T. A.	DSM Interim Report for Test A, DSM Serial 00441.
410-1	30 July 46	014B-H	Frederick, Col. G. D.	Army Ground Group T. G. 1.4, Interim Report for Test A. Encl. B to DSM Serial 00441.
410-2	28 July 46	014J	Lonnquest, Capt. T. C. (Navy)	DSM Bureau of Aeronautics Group. Interim Report for Test A. Encl. C. DSM Serial 00441.
410-3	29 July 46	014K	Forest, Capt. F. X. (Navy)	DSM Bureau of Ships Group. Interim Report for Test A. Encl. A. DSM Serial 00441.
410-4	30 July 46	014L	Mott, Capt. E. B. (Navy)	DSM Bureau of Ordnance Group. Interim Report for Test A. Encl. D. DSM Serial 00441.
410-5	28 July 46	014M	Draeger, Capt. R. H. (Navy)	DSM Bureau of Medicine and Surgery Research Group. Encl. E. DSM Serial 00441.
410-6	28 July 46	014N	Engleman, Capt. C. L. (Navy)	DSM Electronics Coordinating Officer. Interim Report for Test A. Encl. F. DSM Serial 00441.
410-7	26 July 46	014S	Fraser, Comdr. O. W.	DSM Bureau of Supplies and Accounts Group. Interim Report for Test A. Encl. H. DSM Serial 00441.

Ref. No.	Date	Group	Author	Title
410-8	26 July 46	014Y	Lamoreaux, Comdr. R.	DSM Bureau of Yards and Docks Group. Interim Report. Encl. G. DSM Serial 00441.
420	27 Aug 46	014	Solberg, Rear Adm. T. A.	DSM Report on Decontamination of Target Vessels. Interim Report for Test B. Encl. F. DSM Serial 00447.
420-1	27 Aug 46	014	Solberg, Rear Adm. T. A.	DSM Interim Report Test B. DSM Serial 00447.
420-3	20 Aug 46	014J	Dodson, Capt. J. E. (Navy)	DSM Bureau of Aeronautics Group. Interim Report for Test B. Encl. B. DSM Serial 00447.
420-4	27 Aug 46	014K	Forest, Capt. F. X. (Navy)	DSM Bureau of Ships Group. Interim Report Test B. Encl. A. DSM Serial 00447.
420-5	26 Aug 46	014L	Mott, Capt. E. B. (Navy)	DSM Bureau of Ordnance Group. Encl. C. Interim Report Test B. DSM Serial 00447.
420-6	6 Sept 46	014M	Draeger, Capt. R. H. (Navy)	DSM Bureau of Medicine and Surgery Research Group. Interim Report Test B. Encl. E. DSM Serial 00447.
420-7	22 Aug 46	014N	Rice, Comdr. J. E.	DSM Electronics Coordinating Officer. Interim Report Test B. Encl. E. DSM Serial 00447.

Ref. No.	Date	Group	Author	Title
420-8	15 Aug 46	014Y	Diberto, Lt. E. T. (Navy)	DSM Bureau of Yards and Docks Group. Interim Report for Test B. Encl. D. DSM Serial 00447.
421	27 Aug 46	014B-H	Frederick, Col. J. D.	Army Ground Group. Final Report of Atomic Bomb Tests. T. G. 1.4.
430	6 July 46	014	Solberg, Rear Adm. T. A.	Gross Damage Report Test A. DSM Serial 00174.
440	5 Aug 46	014	Solberg, Rear Adm. T. A.	Gross Damage Report Test B. DSM Serial 00443.
450	19 Dec 46	014	Solberg, Rear Adm. T. A.	Final Report on Tests A and B by BuShips Group.

5. References of the 500 Series.

Below are listed references by other persons and groups within Operation Crossroads.

Ref. No.	Date	Group	Author	Title
500				Crossroads Handbook, LA 550.
510-1	9 Sept 46	1.5.2	Cullen, Col. P. T.	Descriptions of Bursts.
510-2	10 Sept 46	1.5.2	Cullen, Col. P. T.	Aircraft Orbit Positions.
510-3	30 Sept 46	1.5.2	Cullen, Col. P. T.	Photo Installations in Aircraft.

6. References of the 600 Series.

Below are listed references by groups and individuals not in Operation Crossroads.

Ref. No.	Date	Group	Title
601	11 July 46	Evaluation Board	Preliminary Report on Test A.
602	27 July 46	Evaluation Board	Preliminary Report on Test B.
603	7 July 46	President's Evaluation Commission	Preliminary Report on Test A.
604	27 July 46	President's Evaluation Commission	Preliminary Report on Test B.

APPENDIX V

PHOTOGRAPHS

TEST BAKER

THIS SEQUENCE SHOWS THE B-DAY EXPLOSION. NOS. 1, 2, AND 3 ARE SUCESSIVE FRAMES; NO. 4 IS NOT CONSECUTIVE. NOTE THE MINIMUM OF OPTICAL RADIATION IN NO. 2.

REF: 16 MM ROLL #1428 E.

NO. 1

NO. 2

NO. 3

NO. 4.

Secret

APPENDIX V

THE FOLLOWING PHOTOGRAPHS FROM TEST B ILLUSTRATE:

1 Test-B fireball breaking through surface of the Lagoon.

2 Same an instant later, showing embryo shock wave forming on each side of the column. Note sudden bend in shock wave close to the column.

3 Same an instant later. Shock wave now appears nearly spherical.

4 Aerial view of Test B prior to formation of condensation cloud. Shock wave has engulfed SARATOGA (left) and ARKANSAS (right).

5 Start of formation of condensation cloud.

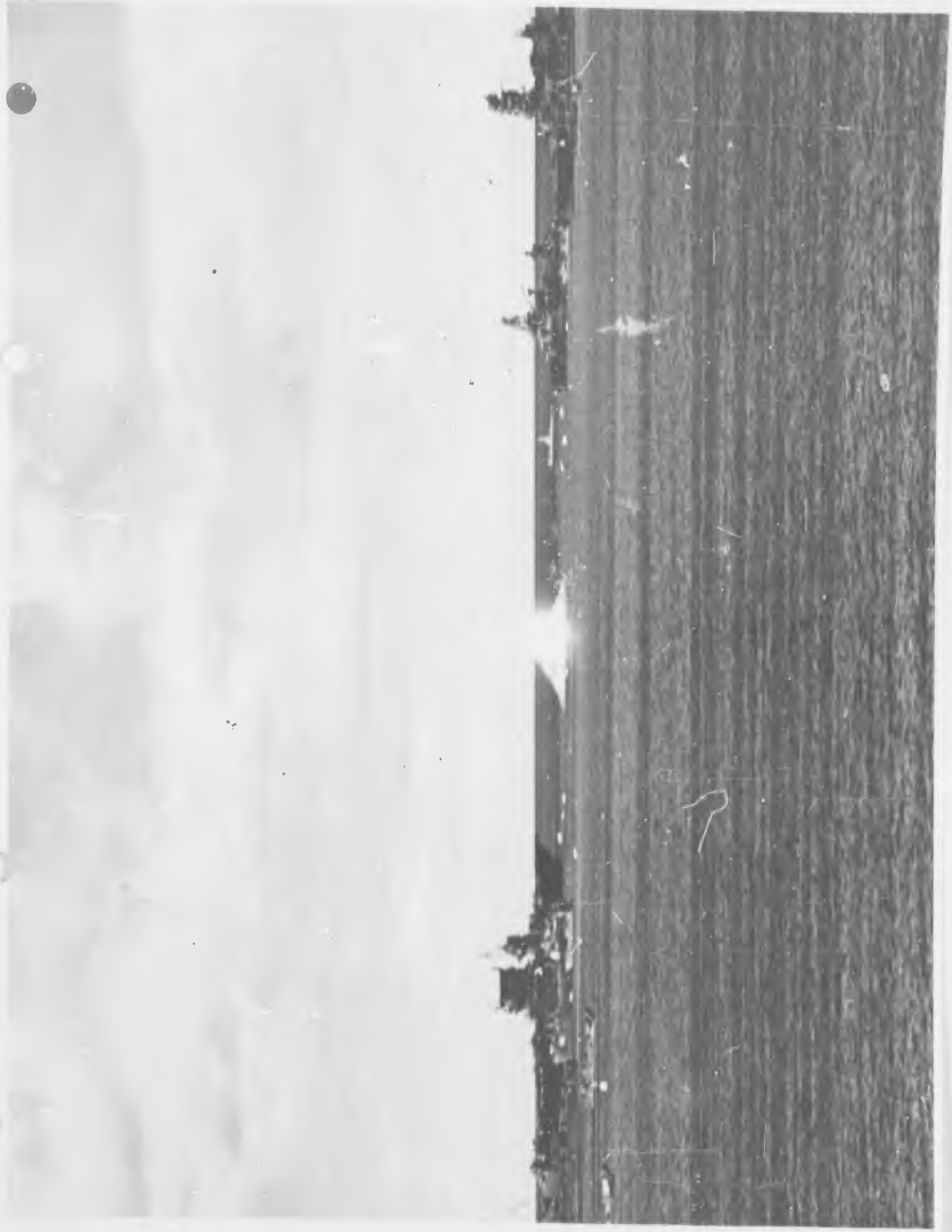
6 Aerial view of condensation cloud in early stage. Streaks to left of center, top of column, presumably show paths of fragments from LSM-60.

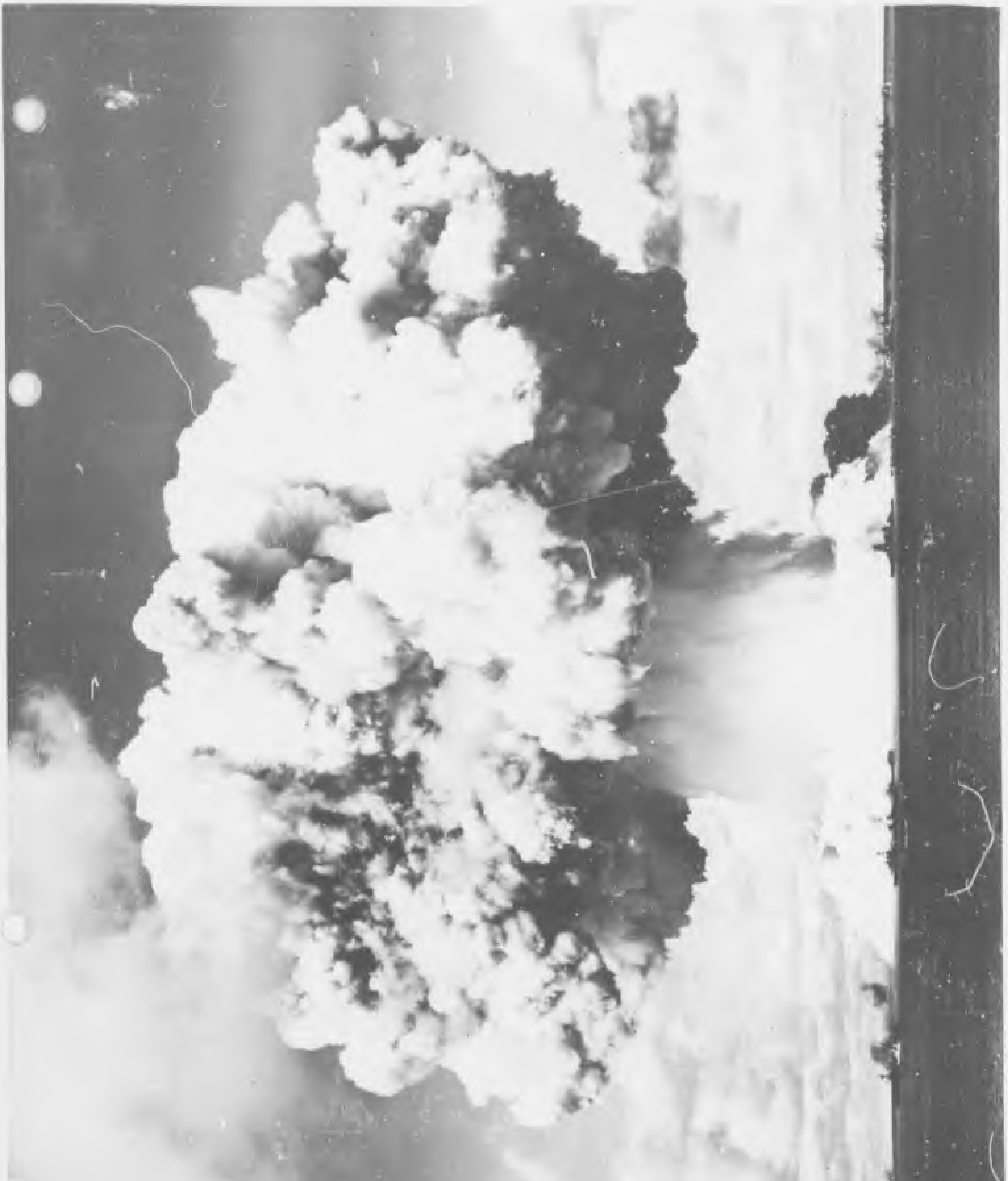
7 Base surge produced by descending column.

8 PENSACOLA: ruptured 16 in. X 3/8 in. stanchion extending from boiler foundation to second deck. (Stanchion was perhaps weakened in Test A)

9 PENSACOLA: Gun turret #2 lifted off the base ring.

10 PENSACOLA: Forward engine room; cracks in #4 astern turbine foundation casting.





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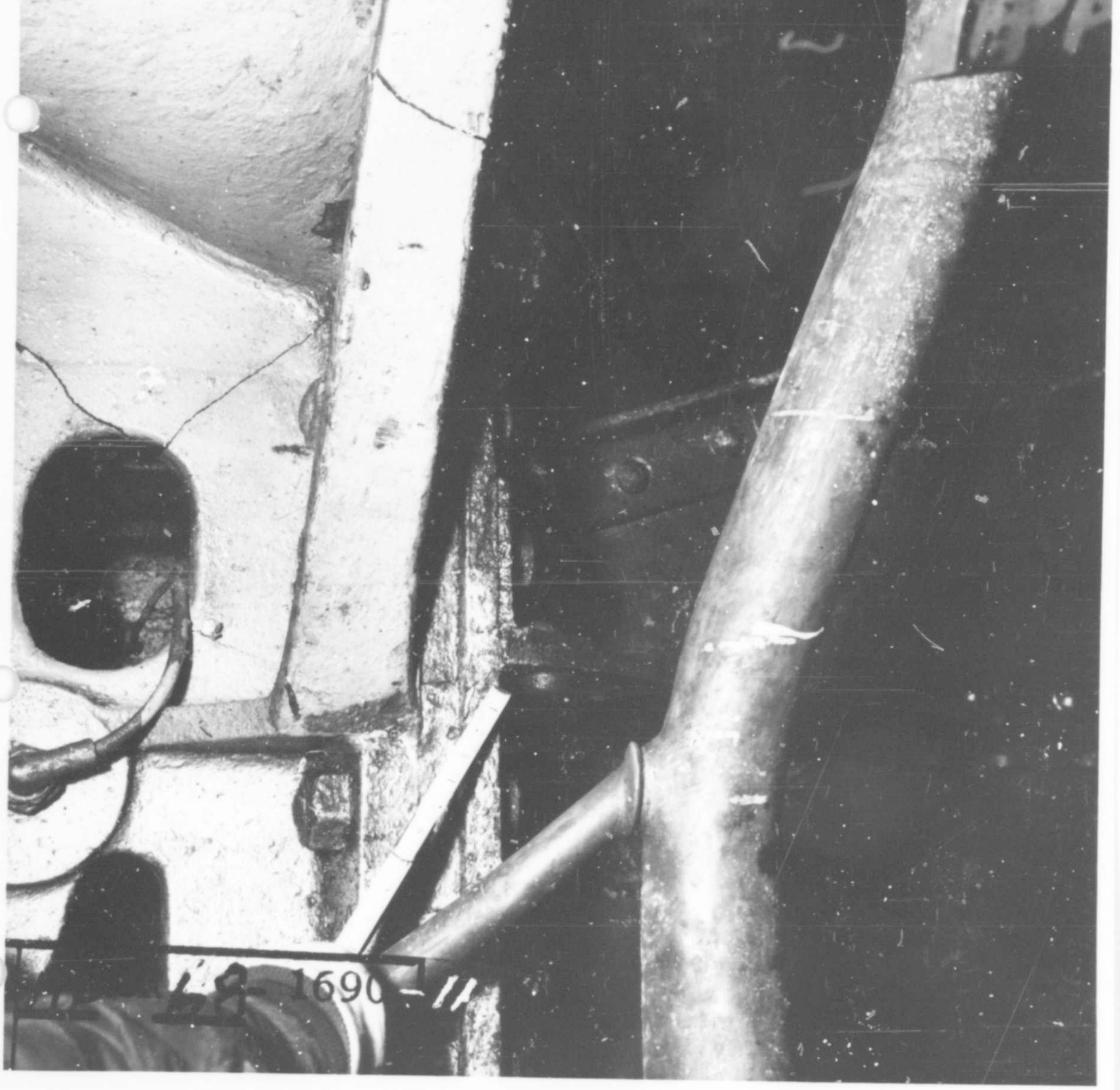
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INDEX OF PERSONS

(Abbreviations: S- Summary; A- Appendix)

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SECRET

INDEX OF CHIEF SUBJECTS

A summary of the Operation is contained in the front of the Report. A "Finder Tab" system is included to facilitate finding chapters on results. A table of contents precedes each chapter.

Abbreviation: A- Appendix

SECRET

AD- 367490

SECURITY REMARKING REQUIREMENTS

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REVIEW ON 18 NOV 64

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