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Nuclear Test Personnel Review --

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1. KEY WORDS (Continue on reverse side if necessary and identify by block number)

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AFSWC
Fallout
Decontamination
Atmospheric Nuclear Tests
Rad-Safe
Oceanic

1. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the activities of DoD participation in the atmospheric nuclear test series, Operation WIGWAM, which involved only one deep underwater shot in the Pacific, approximately 500 miles southwest of San Diego, CA. WIGWAM was essentially a single service operation with minimal AEC contractor participation. The various levels at which DoD personnel participated within the Joint Task Group 7 are identified. The Naval Ocean Systems Command is acknowledged for their analysis and assessment of the reliability

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The Defense Nuclear Agency Action Officer, Major H. L. REESE, USAF, under whom this work was done, wishes to acknowledge the research and editing contribution of numerous reviewers in the military services and other organizations in addition to those writers listed in block 7.

20. ABSTRACT (Cont.)
of radiological exposure records and data (Appendix J). Tech Reps, Inc., under separate DNA contract, is acknowledged for their contributions to Chapter 3 and Appendix I. The AEC and DoD criteria and procedures for Rad-Safe are included. Those projects related to DoD mission activities are described as to purpose, agency, operations, and Rad-Safe aspects.

Table E-1. Fixed gamma intensity-time recorders (Reference 6). (Continued)

Station	Ship	Detectors	Location and Purpose
32	39	Am, Bm, Cm, Dm	Main deck, forward of superstructure, port, deck contamination studies
39	39, 40	Am, Bm, Dm	Wheelhouse; space radiation level and entry
57	40	Bm, Dm	Engine room aft; space radiation level and entry
58	39,40	Bm, Cm, Dm	Engine room, firing aisle; space radiation level and entry
64	39	Bm, Dm	Recorder room; space radiation level and entry
64	40	Bm, Cm, Dm	Recorder room; space radiation level and entry
67	39,40	Bm, Cm, Dm	Over Hold 4, hatch cover, main deck, starboard; deck contamination studies
68	39,40	Bm, Cm, Dm	Over Hold 4, hatch cover, main deck, port; deck contamination studies

Table E-1. Fixed gamma intensity-time recorders (Reference 6). (Continued)

Station	Ship	Detectors	Location and Purpose
19	39	Bm, Cm, Dm	Over Hold 2, hatch cover, main deck shielding studies
20	39	Am, Bm, Cm	Over Hold 2, hatch cover, main deck; shielding studies
22	39	Bm, Cm, Dm	Over Hold 2, hatch cover, main deck; shielding studies
23	39	Am, Bm, Cm	Over Hold 2, hatch cover, main deck; shielding studies
24	39	Bm, Cm, Dm	Over Hold 2, hatch cover, main deck; shielding studies
25	39,40	Bm, Cm, Dm	3-ft below Hold 2, hatch cover, center; space dose and shielding studies
26	39,40	Bm, Cm, Dm	1-ft above second deck, Hold 2, center; space dose and shielding studies
27	39,40	Bm, Cm, Dm	Hold 2, 11-ft below second deck, center; space dose and shielding studies
28	39,40	Bm, Cm, Dm	Hold 2, 22-ft below second deck, center; space dose and shielding

Table E-1. Fixed gamma intensity-time recorders (Reference 6).

Station	Ship	Detectors*	Location and Purpose
2	40	Am, Bm, Cm, Dm, Em	Keel, forward; sea contamination evaluation
7	40	Am, Bm, Cm,	Hold 1, manifold space; radiation level and entry†
9	39,40	Am, Bm, Cm	Forward Kingpost; wash-down evaluation and radiation evaluation from distance
13	39	Am, Bm, Cm	Over Hold 2, main deck, starboard; deck contamination and shielding studies
13	40	Bm, Dm	Over Hold 2, main deck, starboard; deck contamination and shielding studies
14	39,40	Bm, Dm	Over Hold 2, main deck, port; deck contamination and shielding studies
15	39	Bm, Cm, Dm	Over Hold 2, Main deck, center; deck contamination and shielding studies
15	40	Am, Bm, Cm	Over Hold 2, main deck, center; deck contamination and shielding studies
17	39	Am, Bm, Cm	Over Hold 2, hatch cover, main deck; shielding studies

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*See Table E-2 for definition.

†Used to determine times for safe entry and staying times, regarding operational radiological safety.

APPENDIX E
RADIOLOGICAL INSTRUMENTATION

E-1 YAG-39 AND YAG-40 (Reference 6).

The responsibility for radiological instrumentation on YAG-39 and YAG-40 during Operation WIGWAM was undertaken by the U.S. Naval Radiological Defense Laboratory. The instrumentation was placed aboard both YAGs at stations as listed in Table E-1. These stations measured the continuous gamma intensity recorders as a function of time. The stations operated on the principle that radiation flux, incident on an ionization chamber, discharged preset automatic- recharging capacitors. Two to four detectors, as well as dosimetry film, were also placed on each station aboard the two YAGs. Detector ranges are illustrated in Table E-Z.

Survey teams on the YAG-39 and YAG-40 used Army Navy/Portable Detector Radiacs (AN/PDR) to supplement the continuous gamma recorders. The weather-deck measurements were taken 3 feet above the deck surface and the hold measurements were taken in contact with the hull. However, because the ship decontamination procedure studies were cancelled, YAG-40 was given only one complete survey, and YAG-39 was cursorily surveyed.* The reason for cancellation of the studies is not given in Reference 6.

Beta radiation intensities were measured using Naval Radiological Defense Laboratory (NRDL) RBI-12 beta probes equipped with an extra "hi-lo" switch. These probes superimposed air ion chambers with opposing circuitry in order to eliminate the gamma ionizing effect. All measurements were made with the probe held against pre-specified surface locations.

Although fallout detectors were placed aboard the two YAGs under the supervision of Project 2.7, fielded by NRDL, the equipment failed, so that no fallout data were recorded on either YAG, on the two LCMs, or on the YFNB-12.

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*While in area of operations. Both were completely surveyed upon arrival in San Francisco after the operation.

shown in Table D-7. YAG-40 was granted a "limited" operational clearance after spot decontamination.

Table D-7. Results of radiological survey on YAG-40 after arrival at San Francisco Naval Shipyard (Reference 6).

Item	Radiation level,* counts/min	
	Open window	Closed window
Fire sprinkler		
Starboard, approximately frame 82	50,000	3,500
Removable from inside	2,500	600
Contamination inside valve	15,000	2,500
Hangar-deck tie-down channels	50,000	2,000
Roller checks		
Port, approximately frame 5	50,000	20,000
Removable	4,000	
Starboard, approximately frame 5	50,000	20,000
Removable	None	
Hatch wedges (on hatch 2)	50,000	3,000
3-in. gun mounts		
Port	50,000	25,000
Starboard	20,000-40,000	1,000-40,000
Life raft cover (temporarily located starboard, approximately frame 55)	40,000	4,000
Air scoop (port, frame 115, main deck)	50,000	3,000
Diesel intake stack (frame 136)	50,000	7,000
Void vents (starboard, frame 90), patches	50,000	5,000
Lifeboat davit handles (forward, starboard)	50,000	5,000
Hand railing and posts (boat deck, starboard)	50,000	5,000
Deck at after corners of pilot house	50,000	25,000
Davit (aft, starboard corner of top of deckhouse)	40,000	7,000
Stay brace for galley stack, patches	50,000	20.000
Signal halyard hooks	30,000	1.000
Cleat (port, top of deckhouse)	50,000	20,000
Door to deckhouse (starboard, frame 70)	50,000	2,000

*The survey was performed with two Berkeley survey meters, Model 2750-1. The instrument indication was in counts per minute and necessarily required a calibration in order to correlate readings with final-clearance level.

clearance required of all ships prior to inactivation or disposal. It is desirable that all ships satisfy the requirements for final clearance as early as practicable. The final clearance gamma-radiation level for YAG-39 was defined as 1.5 mR/h, corresponding to a meter reading of 4500 CPM, closed window (CW). Final-clearance beta-radiation fixed level corresponded to a meter reading of 22,500 CPM, open window (OW).

Table D-6. Results of radiological survey on YAG-39 after arrival at San Francisco Naval Shipyard (Reference 6).

Item	Radiation level,* counts/min Open window	Closed window
Washdown sprinkler heads		
Portside of hatch 4	50,000	3,000
Top of deckhouse (4 heads)	20,000-50,000	500-6,000
Jack-staff base	50,000	10,000
Lifeboat supports (boat deck)	25,000	2,000-4,000
Lifeboat davits (boat deck)	15,000-50,000	1,500-4000
Scuppers: boat deck, port, forward	20,000-50,000	500-2,000
Wrapped wire line, starboard, aft lifeboat rigging	50,000	2,000
Washdown diesel No. 2: intake manifold	20,000	1,000
Removable (wipe count taken on manifold that had been removed)	4,000	

YAG-40 entered the contaminated surface area at H + 46 minutes and remained there for 2.5 hours during the first 24 hours after detonation. The resulting weather-deck dosage was of 1.6 R, and the dosage in the internal spaces was less than one-tenth of this. Hull and piping system contamination was insignificant. The radiation levels of YAG-40 upon arrival at San Francisco are

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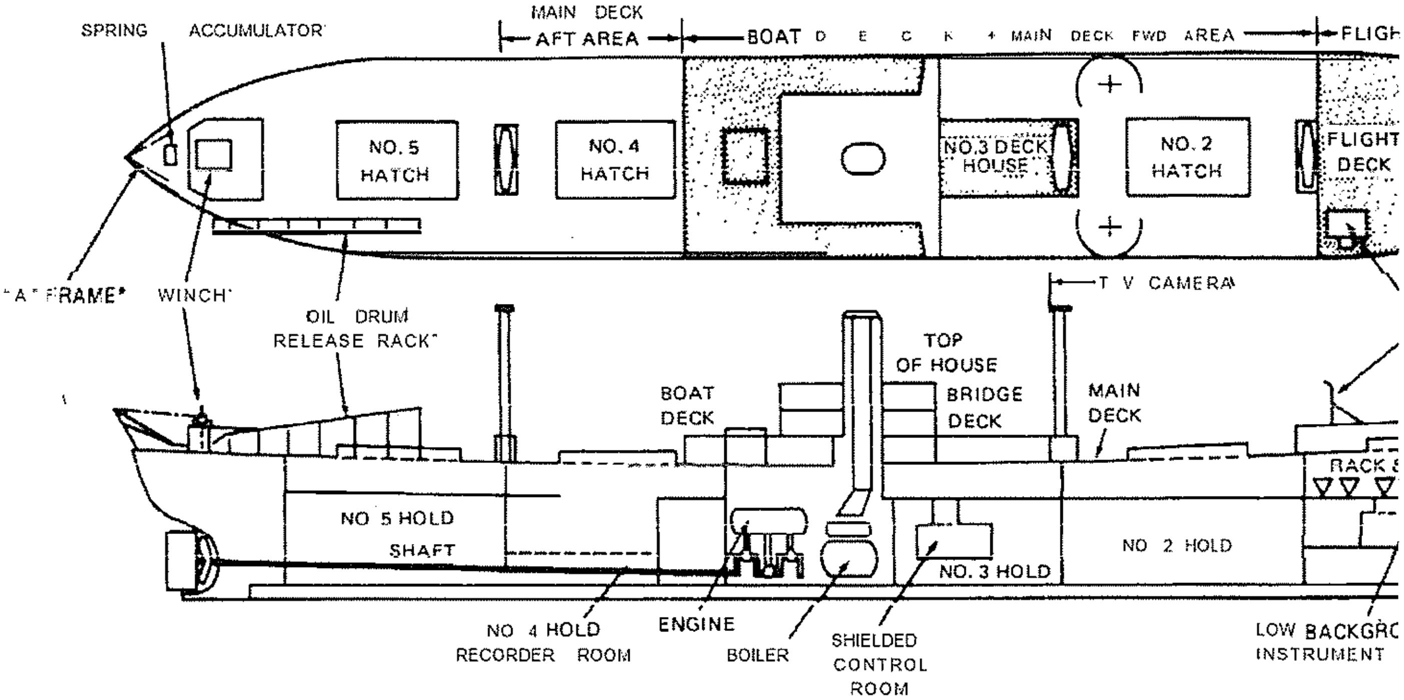
*The survey was performed with two Berkeley survey meters, Model 2750-1. The instrument indication was in counts per minute and necessarily required a calibration in order to correlate readings with final-clearance level.



*FACILITIESON YAG 400NLY

Figure D-13. Plans and side view showing special facilities on YAG-39 and YAG-40.

considerable time was spent searching the wrong area under the impression that the deep drogues in the shot area had not survived some strong turbulence (Reference 7). On D + 4 days, however, these deep drogues were found by a Task Force element some miles to the south. On the first cast the Horizon took in the area of these drogues, the deep activity was discovered. It was subsequently surveyed satisfactorily and its total content of radioactive material was ascertained. In all some 500 vertical casts were made by the Scripps vessels to D + 10 days.

D-5 RADIOLOGICAL ENVIRONMENT ON SHIPS (Reference 6).

Two of the ships which encountered regions of high radioactivity were YAGs-39 and -40. The profile and plan of the ships are shown in Figure D-13.

Airborne activity, moving downwind, reached the YAG-39. At H + 3 minutes, the radiation level on the deck was 400 R/h. This reading persisted about 6 minutes during passage of the cloud. Interior spaces protected by one layer of ship skin were exposed to about 6 to 12 R during the same period. Other spaces had significantly lower readings. The radiation level on deck had decreased to about 9 mR/h at H + 1 hour, and about 1 mR/h at H + 19 hours. Although washdown with contaminated water increased the radiation level to 500 mR/h on D + 1 day, dosage was not increased materially.

The radiation levels upon the ship's arrival at the San Francisco Naval Shipyard are given in Table D-6. After returning to port, YAG-39 was granted an operational clearance following a spot decontamination. Operational clearance indicates that all normal operations, repairs and maintenance can be carried out without radiological hazard, provided the applicable precautions for handling contaminated materials are observed. This is the clearance required for the normal operation of active ships. Final clearance, on the other hand, is the

The M/V Horizon also made multiple traverses of the contaminated water. Approaching the northeast perimeter of the area, using navigational and radiac equipment to guide her, the Horizon first encountered radioactivity at D + 90 minutes at a 35-meter depth and approximately 6,000 yards from surface zero. This distant intrusive layer apparently had moved along the bottom of the upper mixed layer at 1 1/2 knots. After this finding, the approach to the detonation point was continued with increased care, but no further submerged activity was found.

Water with 1.5 R/h surface activity was encountered at H + 173 minutes. Just north of this point, a deep cast was taken, and no radioactivity was encountered to 700 meters. This unexpected result actually was due to the coincident unanticipated shift of ocean surface currents at this time, but as this shift was then unknown, it misled the party into believing that no deep radioactivity existed.

At H-hour the shock caused a minor breakage in a pipeline on the Horizon, incapacitating her at this critical time, and because she was upwind of the contaminated area, she was set down into it by the wind. This resulted in some technical contamination that necessitated what would otherwise have been unnecessary precautions in all further work. When power was finally restored, the Horizon sailed out of the area a mile or two and was washed down and repaired.

The Horizon, T-boat, and later the M/V Baird re-entered the area of surface activity as its intensity became lower. Surveys of, and casts through, this activity were taken on 14 to 17, 19 to 20, and 21 to 22 May. The Horizon's principal task was to discover and measure the deep contamination. This search was greatly impeded by the aforementioned unanticipated shift in shear.* Thus,

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*Whereas earlier studies of the area had indicated that the surface water always moved south or southeast relative to the deeper waters, it was later found that this condition had reversed approximately at shot time.

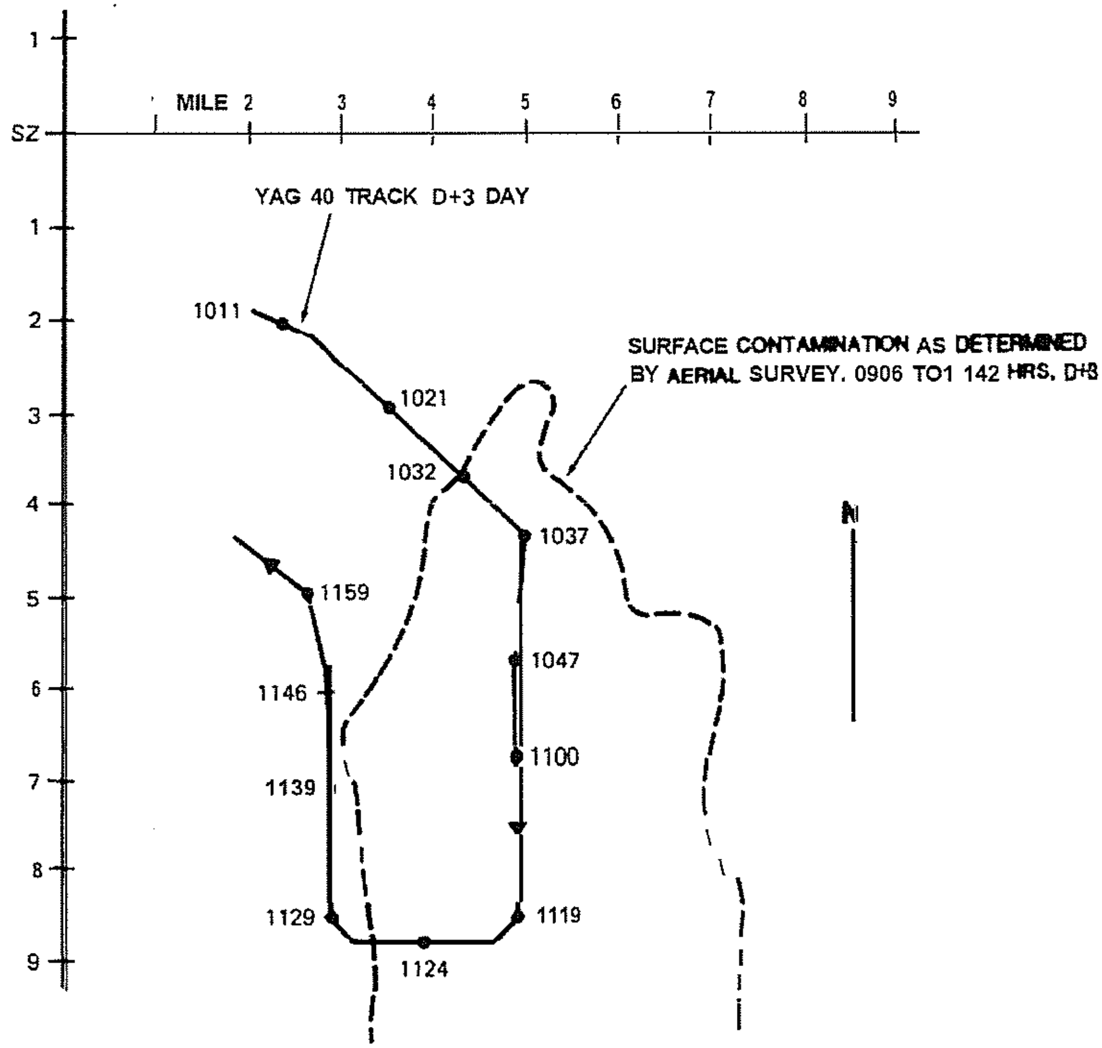

Figure D-12. Track of YAG-40 relative to surface contaminated area, D+3.

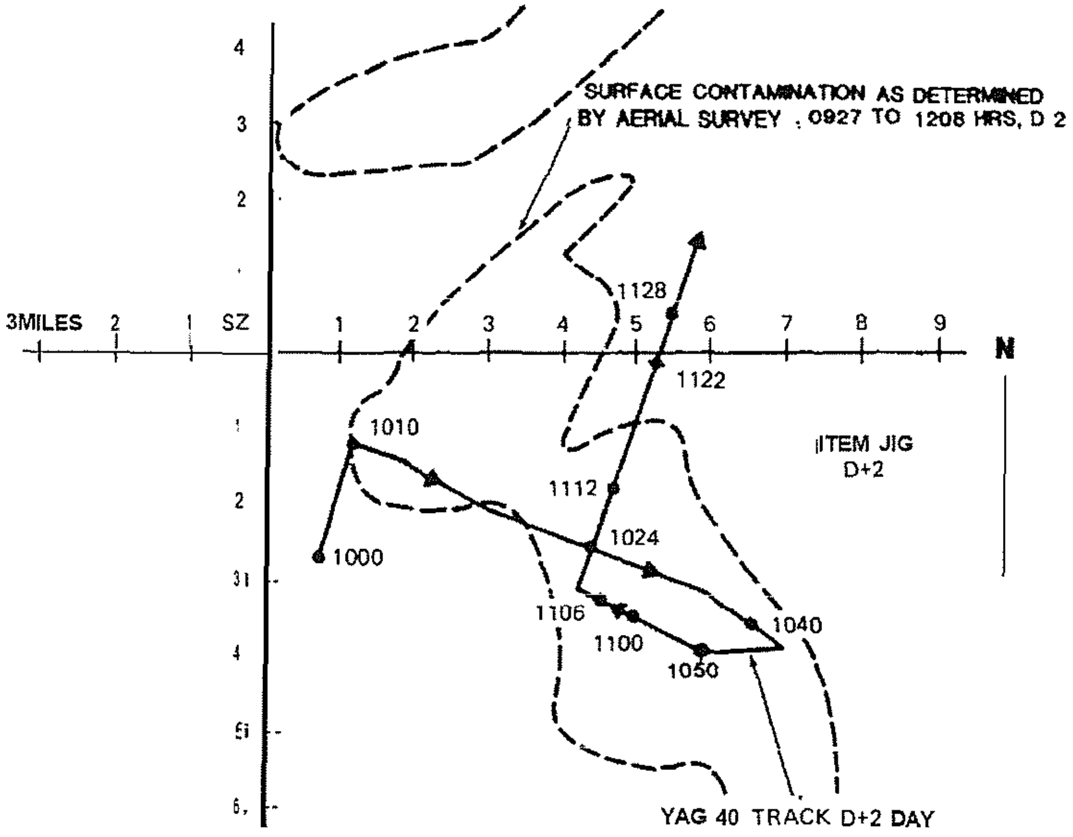

Figure D-11. Track of YAG-40 relative to surface contaminated area, D+2.

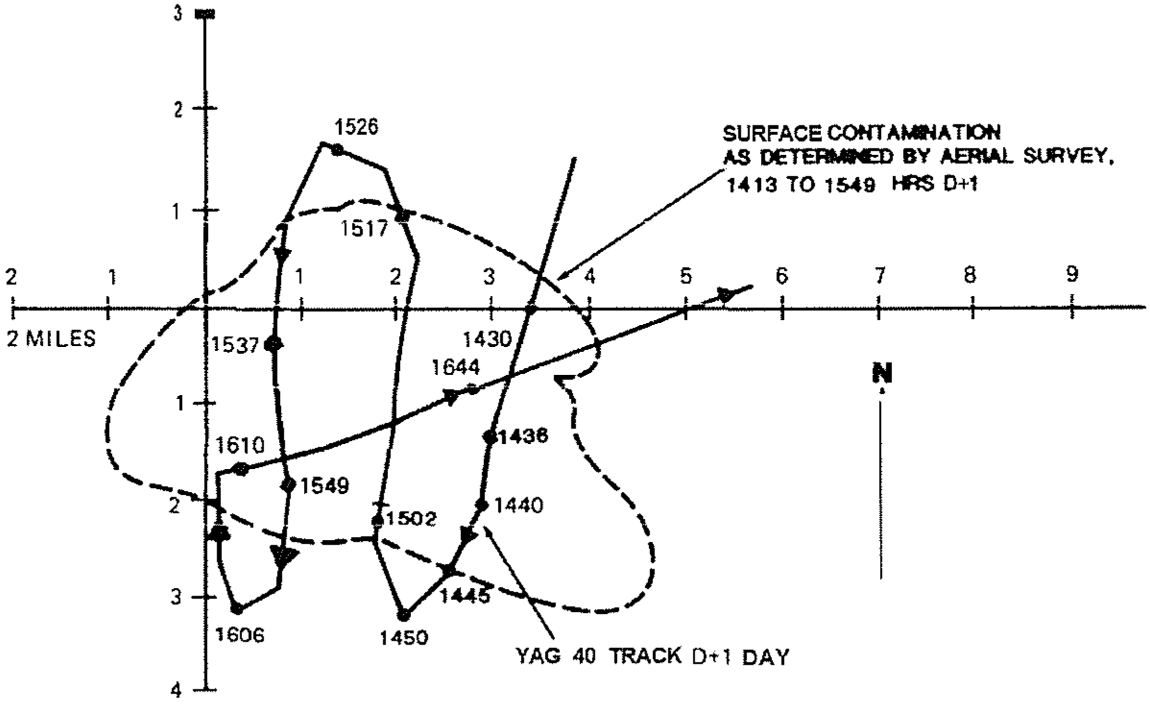

Figure D-10. Track of YAG-40 relative to surface contaminated area, D+1 (second pass).

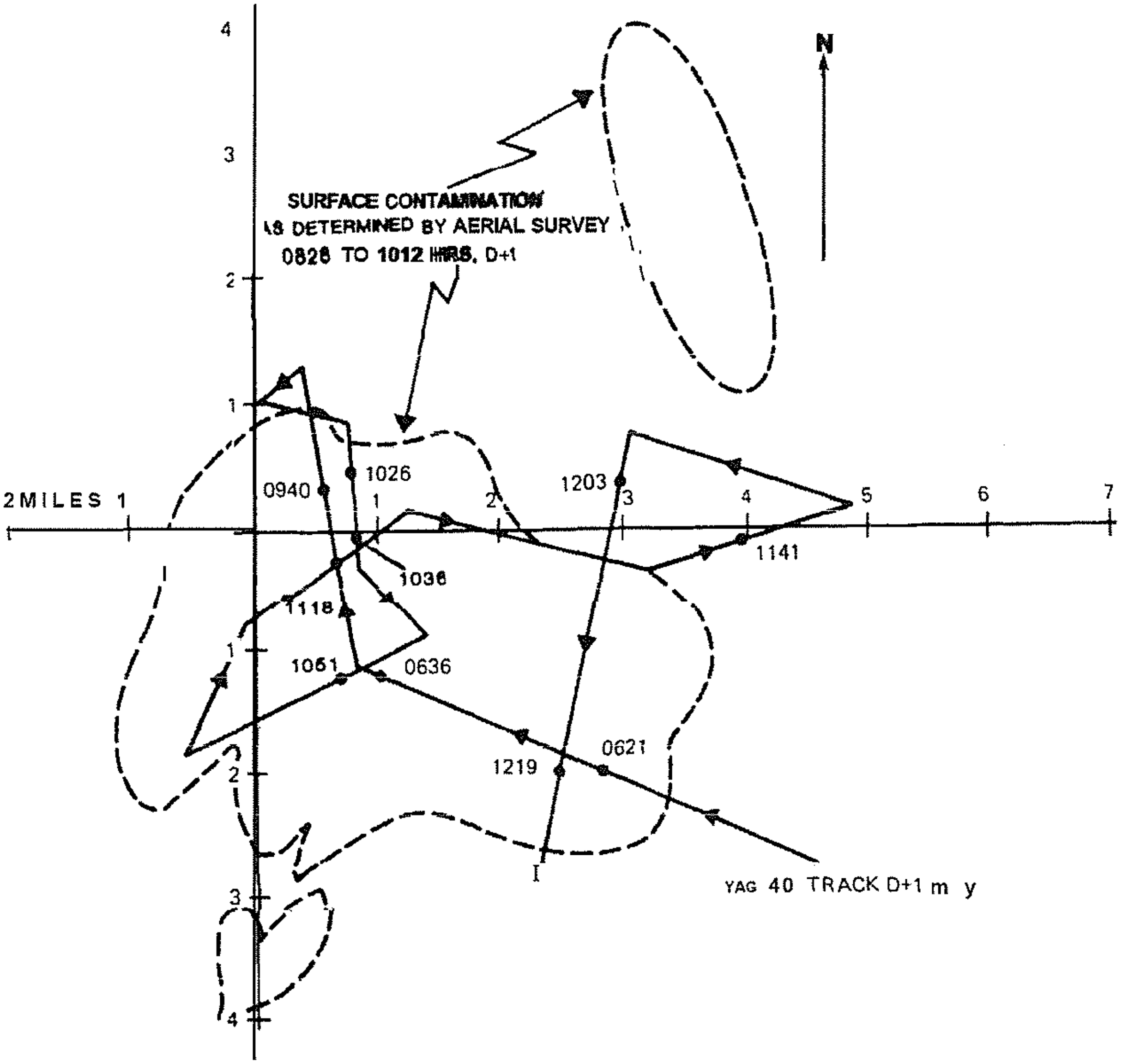

Figure D-9. Track of YAG-40 relative to surface contaminated area, D+

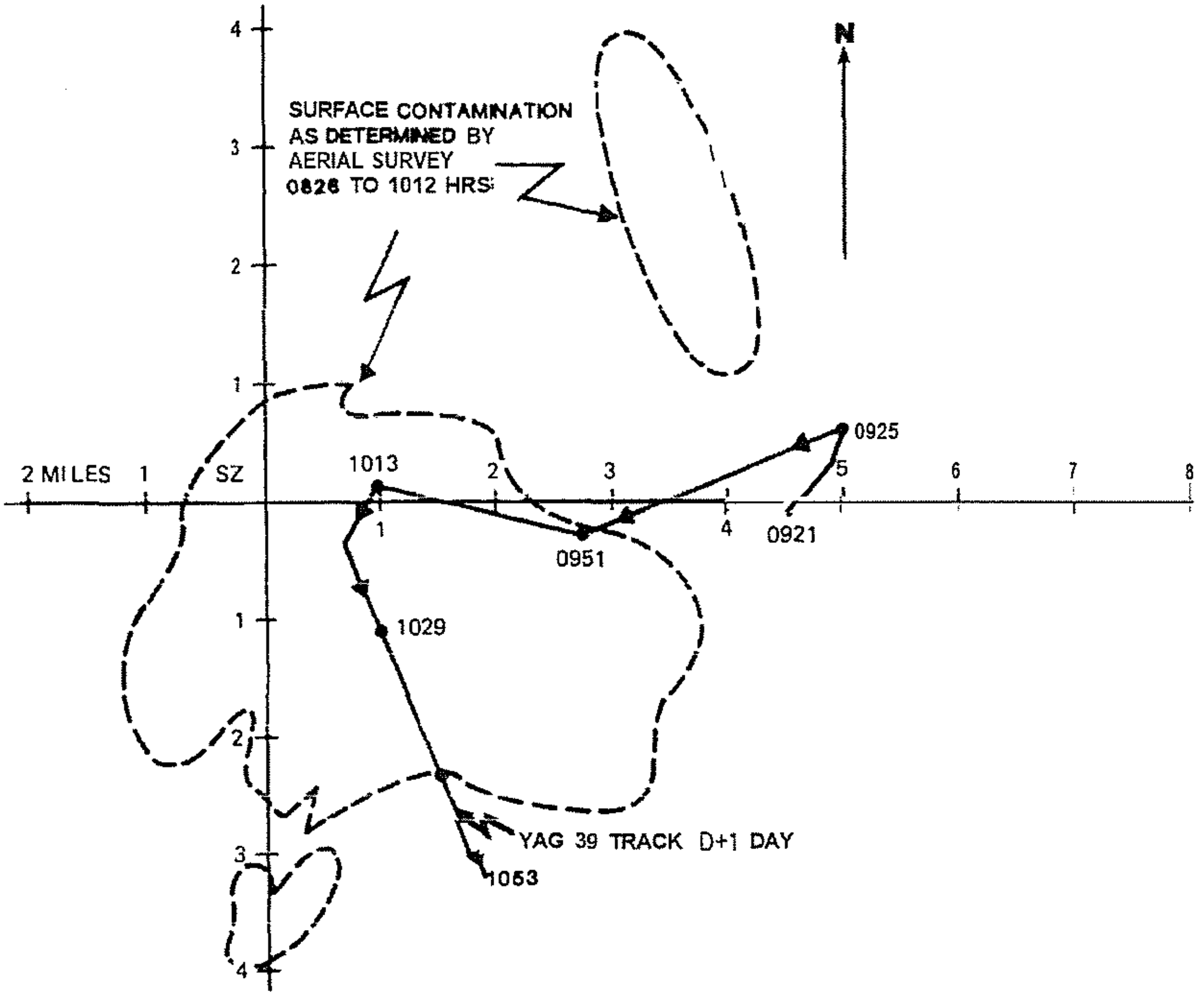

Figure D-8. Track of YAG-39 relative to surface contaminated area, D+1.

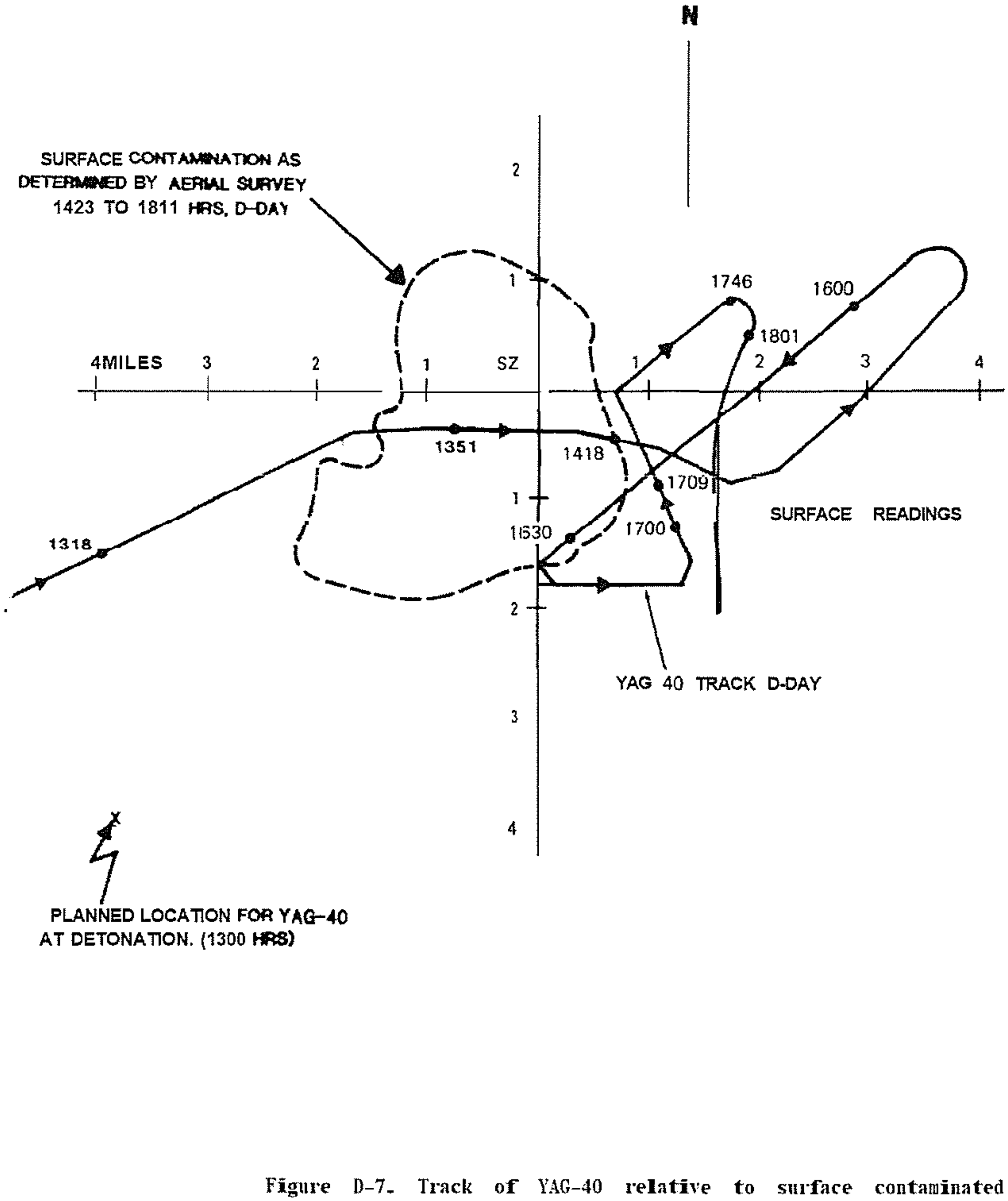

Figure D-7. Track of YAG-40 relative to surface contaminated area, D-day.

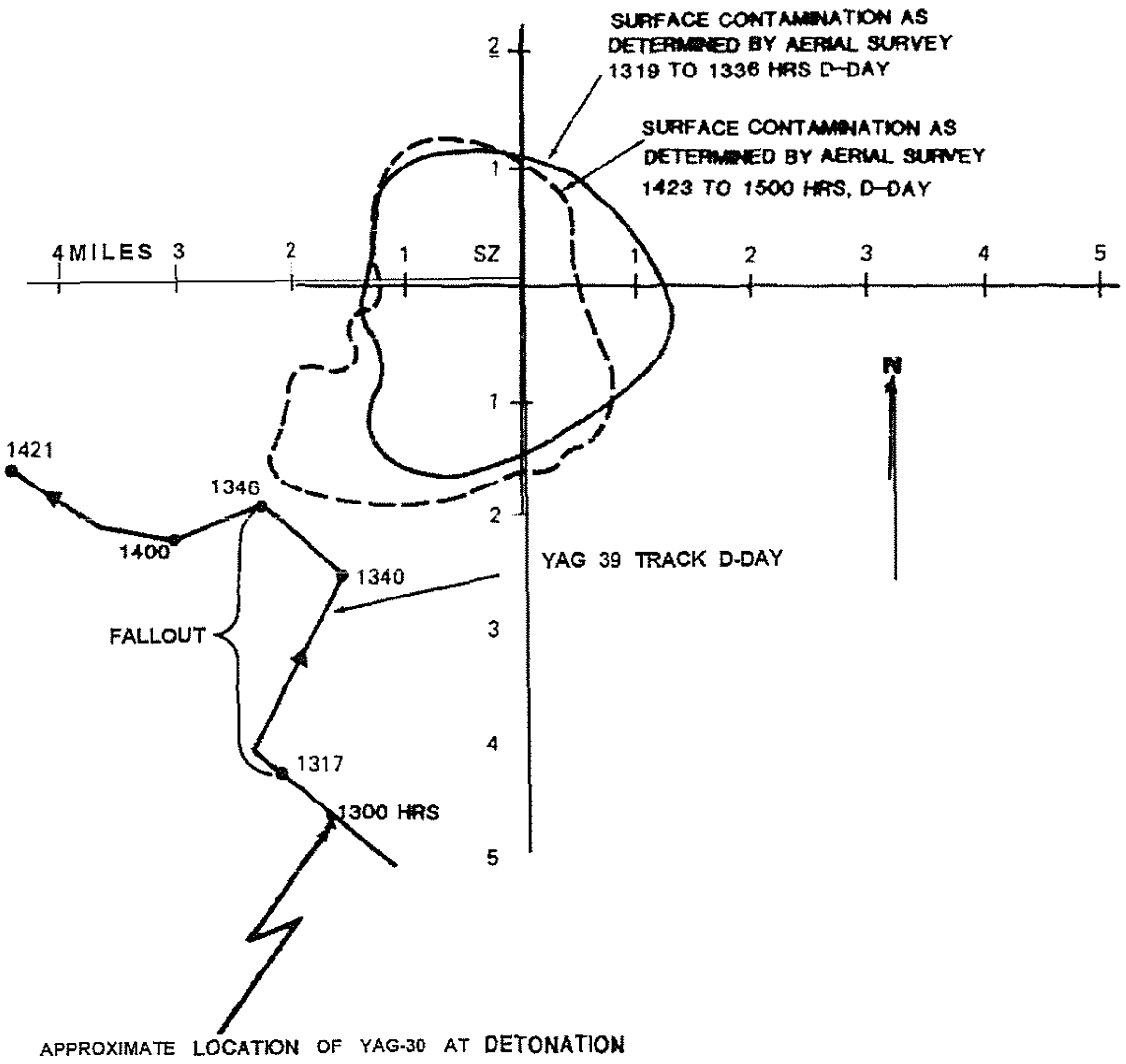

Figure D-6. Track of YAG-39 relative to surface contaminated area, D-Day.

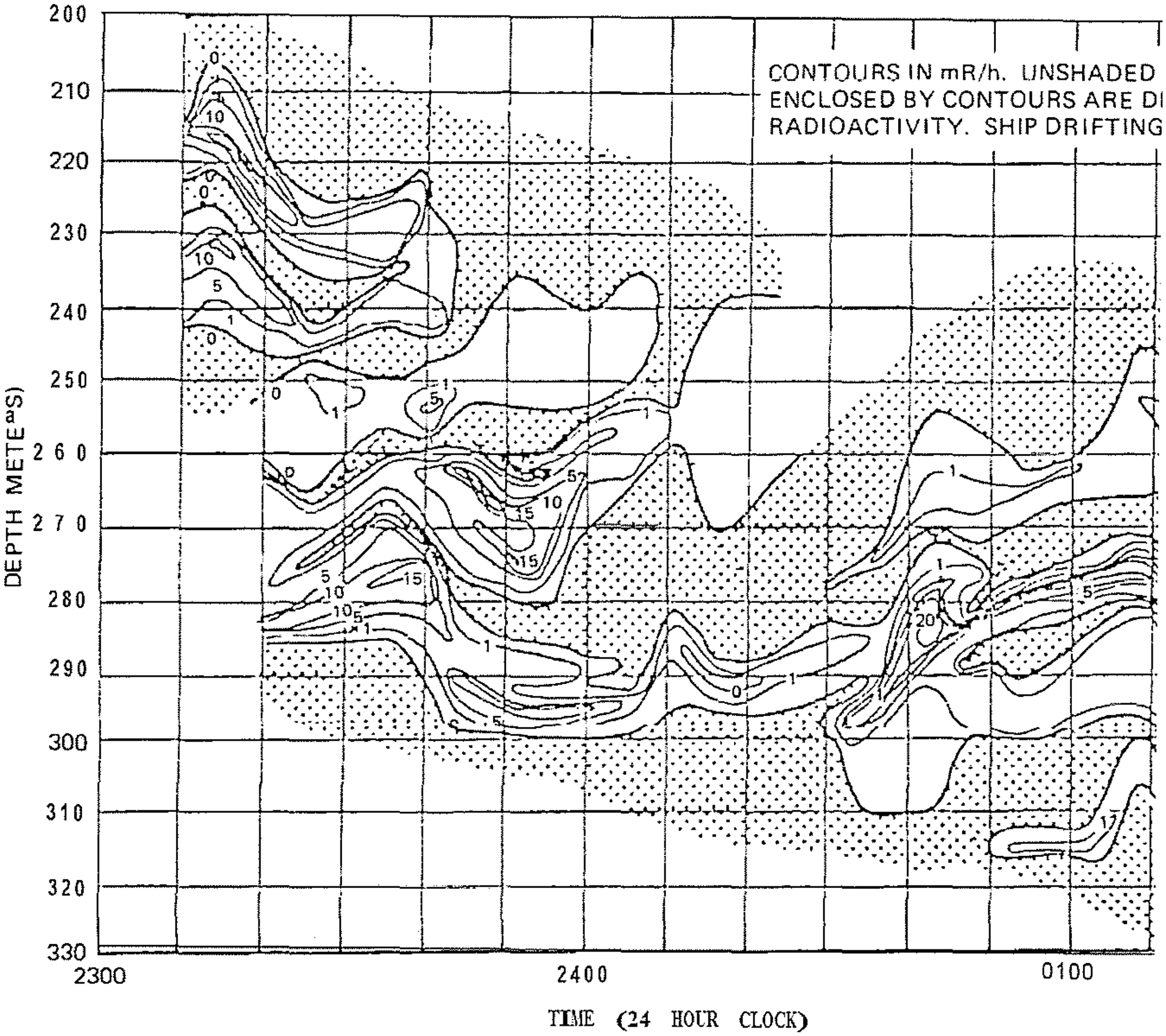

Figure D-5. Radioactivity versus time, 18 May 1955.

Table D-5. Maximum thickness of surface layer activity (Reference 7).*

Time	Surface	Maximum Depth of Penetration
D+		meters
9.9 hours	Horizon sonde	32
12.0 hours	Horizon sonde	80
25.1 hours	T-boat sonde	110
46.7 hours	Horizon sonde	67
120 hours	Horizon sonde	80
168 hours	Horizon horizontal	>100 <164
209 hours	Horizon sonde	128
216 hours	Baird sonde	80

The first evidence of submerged activity just below the top of the thermocline was detected by H + 12 hours, but the principal bodies of contaminated water were not found for several days. Laminae of activity were found unevenly distributed in the water to all depths up to 500 meters (1,640 feet). In general, thin laminae were found to be adjacent to regions of high stability. The thin laminae were thought to have been formed in the stable regions as a result of lower turbulence and higher shear (Reference 7). Figure D-5 illustrates the complexity of phenomena below the thermocline.

Figures D-6 through D-12 show the tracks of YAG-39 and YAG-40 which were known to have made multiple traverses of the contaminated water patch.

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*A series of shallow laminae of varying thickness.

APPENDIX D

WIGWAM RADIOLOGICAL ENVIRONMENT

(Continued)

In the surface layer of water, the reduction in the maximum radiation is approximately $R_{max} = 130\ t^{-2}$ where Rmax is in mR/h and t is in days The data basis for this equation is presented in Table D-4 adapted from Reference 7. The reduction in surface activity was a consequence of lateral and vertical mixing as well as radioactive decay. There were indications that mixing had slowed by D + 10 days, possibly because more of the activity reached the stable structure at the thermocline. The thickness of the surface layer of contamination was quite variable. In places, mixing had extended to the thermocline by H + 25 hours. The maximum depth to which the surface layer had penetrated at various times is shown in Table D-5 (Reference 7).

Table D-4. Maximum surface intensity (Reference 7).

Time	Source	R_{max}*
D+		mR/h
27 minutes	Aircraft	5.5×10^{3}
33 minutes	Aircraft	2.3x103
130 minutes	Aircraft	8.0×10^{3}
173 minutes	Horizon deck	6.0×10^{3}
5.2 hours	Aircraft	3.2×10^{3}
9 hours	Horizon deck	1.8×10^{2}
9.9 hours	Horizon sonde	1.8×10^{2}
20 hours	Horizon deck	3.2×10^{2}
24 hours	Aircraft	1.3×10^{1}
25.1 hours	1-boat sonde	4.0×10^{1}
28.5 hours	I-boat sonde	9.4×10^{1}
28.3 hours	T-boat sonde	4.3×10^{1}
38.9 hours	Horizon sonde	1.5×10^{1}
44 hours	Aircraft	1.8×10^{1}
46.7 hours	Horizon sonde	9.0×10^{1}
52.5 hours	T-boat mode	1.0×10^{1}
168 hours	Aircraft	7.0
171 hours	1-boat sonde	10.0
198 hours	Aircraft	<2.0
113 hours	Horizon sonde	1.0×10^{1}
119.8 hours	Horizon sonde	1.1×10^{1}
121.5 hours	Horizon sonde	1.1×10^{1}
225.2 hours	Horizon	8.0
163 hours	Horizon deck	1.6
169 hours	Horizon sonde	1.0
208 hours	Horizon sonde	5.0
228 hours	Baird sonde	0.6

*Aircraft results, reduced to 3 feet, above water, have arbitrarily been multiplied by 2 and over-the-side measurements on deck have been multiplied by 4 to roughly reduce these measurements to the *in situ* measurements of the probe.

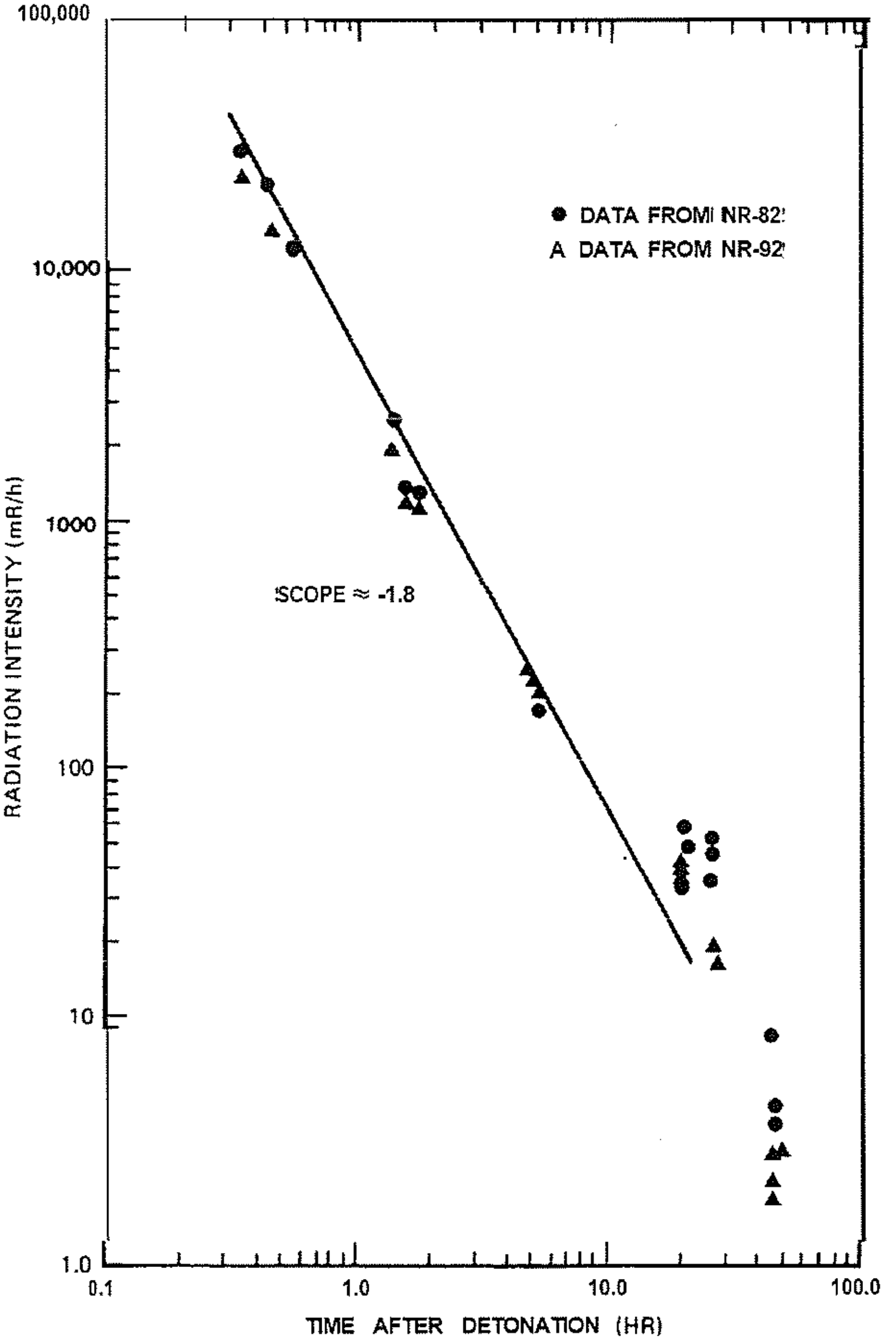

Figure D-4. Average radiation intensity 3-ft. above the surface.

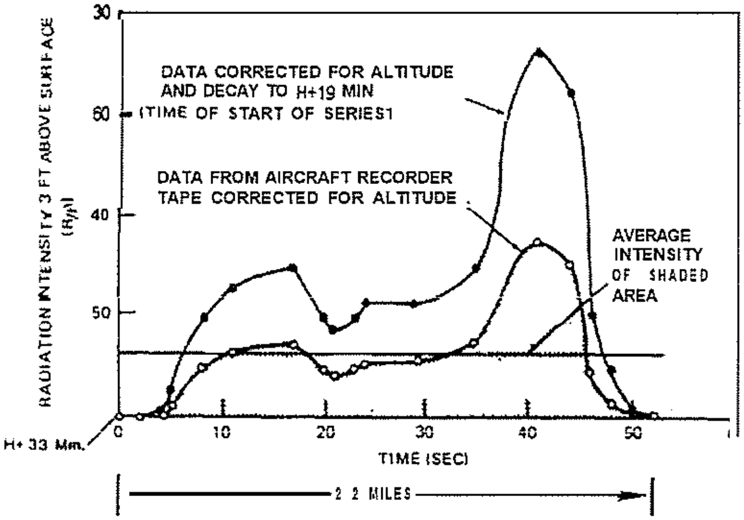

Figure D-3. Estimated radiation intensity of the contaminated water patch. Pass A-3, Survey No. 1 (See Table D-2).

of the ocean resulted in a relatively low-level radiological hazard above the water surface within a few hours.

Table D-3. Area of surface activity.

Time (D+)	Source	Area (Sq. mi.)
0.5 hour	Aircraft	5.5
1 day	Aircraft	13.1
1.7 days	Aircraft	19.0
2.7 days	Aircraft	25.4
4 days	Aircraft	80.3*
5.5 days	Horizon	53.2
7.5 days	Horizon	189.0

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*This result was not heavily weighted. The low maximum intensity measured at that time (see Table D-4) makes the available data questionable.

Table D-2. Principal aerial survey results.*
(radiation intensity at 3-ft. altitude)

		SURVEY 1 (NR-82)			SURVEY 2 (NR-92)		
PASS	STARTING TIME, hr†	AVERAGE, mR/h	MAXIMUM, mR/h	LENGTH OF PASS MILES	AVERAGE, mR/h	MAXIMUM, mR/h	LENGTH OF PASS MILES
A-1	0 33	32,100	48,200	2.5	24,000	70,000	2.5
A-2	0 45	23,200	48,200	2 4	15,000	67,200	3 0
A-3	0 55	12,700	34.700	2.2	5,800	31,400	2 5
B-1	1 39	2,600	4,400	2 0	2,050	3,810	2 2
B-2	1 51	750	2,500	1 7		3,530	
B-3	1 57	1,400	3,190	2 2	1,200	2,580	2.2
C-1	1 73	1,300	2,600	2 4	1,150	2,300	2.5
c-2	1.87				275	1,570	1 1
c-3	1 96	400	840	1 7		896	
D-1	2 16				460	1.060	2 8
E-2	4.81	79	154	1 0			
E-6	5.09				238	336	2 4
E-8	5 21	172	258	2.2	224	314	2.3
E-10	5 34				217	297	2 3
E-3	4 87	6 0	16	2.8			
E-4	4.97	1.1	5.0	2.7	PROBABLY	FALLOUT	
E-5	5 02	1 4	4.5	2.5			
F-2	5 48	108	179	1 7	155	263	1 7
F-3	5 57				104	129	1 0
F-8	5 87	112	162	2 7			
F-9	5 97				98	151	1 4
G-1	19.47				36	66	2.5
G-2	1952	34	69	3.5	42	95	3.6
G-13	20 47	57	128	2 6	38	102	3 6
G-14	20.57	47	98	3.3			
H-0	25 22	45	112	3.8	15	40	4 1
H-3	25 53				16	40	4 4
H-7	25 87	35	72	5 3			
H-9	26 03	50	92	3 4	19	40	3 5
I-0	44 45	8 2	16	3 1			
I-3	44 95				2 8	4 8	3 6
I-6	45 17	3 7	7.0	2 9			
I-9	45 49	3 6	7 4	3 5			
I-11	45 67				2 0	4 1	3 2
I-12	45 78				1.8	3 6	3 2
J-1	45 88	4 4	7 8	3 1			
J-2	45 97	3 6	7.0	3 5			
J-6	46.31	3.6	7 0	5.8			
J-7	46 38				2 7	4 8	3 0
J-8	46.46				2 5	4 4	1.6
J-12	46 81				2 2	4.4	5 9

*DATA FROM ONLY THREE PASSES PER SERIES ARE INCLUDED, PASSES ARE THOSE THAT HAVE THE LARGEST "AVERAGE INTENSITY" DURING THE SERIES

†THE TIME AFTER DETONATION AT WHICH THE RADIATION FIELD WAS INTERCEPTED

to measure the fallout from WIGWAM were impeded because of sinking of the floating platforms on which some instrumentation was placed, and because of the failure of additional instrumentation. Consequently, little late fallout data were obtained. Although it is possible that airborne activity and fallout could have contributed to the contamination of personnel and equipment, as well as added to the water contamination, estimates in Reference 6 indicate that the radioactivity of the water due to fallout was a factor of 100 or more less than that due to the directly contaminated water area.

D-4 WATER CONTAMINATION (References 6 and 7).

A detailed description of the water contamination is provided by References 6 and 7 which estimate the total water-borne contamination to be 85 megacuries* at H + 120 hours, with 72 percent below the thermocline (>100m) and 28 percent in and above the 60 to 100 meter thermocline.

Figure D-3 from Reference 6 shows an example of the radiation intensity 3 feet above the water surface for a single pass over the contaminated water patch. This contour was produced by aerial survey no. 1, pass A-3, for which data are included in Table D-2. The data in Table D-2 exhibit the combined diffusion and radioactive decay, which is plotted in Figure D-4. The areas of the surface activity contours shown in Table D-3, was obtained from aircraft and Scripps Institution of Oceanography ships during the period D + 5 to D + 8 days. The maximum intensity of the radiation field 3 feet above the water surface is shown in Table D-4. These figures and tables indicate that radioactive contamination

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*The total activity of 85 megacuries at H + 120 hours is in poor agreement with the 63 megacuries obtained from the 27 megacuries H + 240 hour estimate (French 1955) using the $t^{-1.2}$ decay model. This is in part attributable to the difficulty in converting mR/h readings to curies and in integrating over a complex three-dimensional volume.

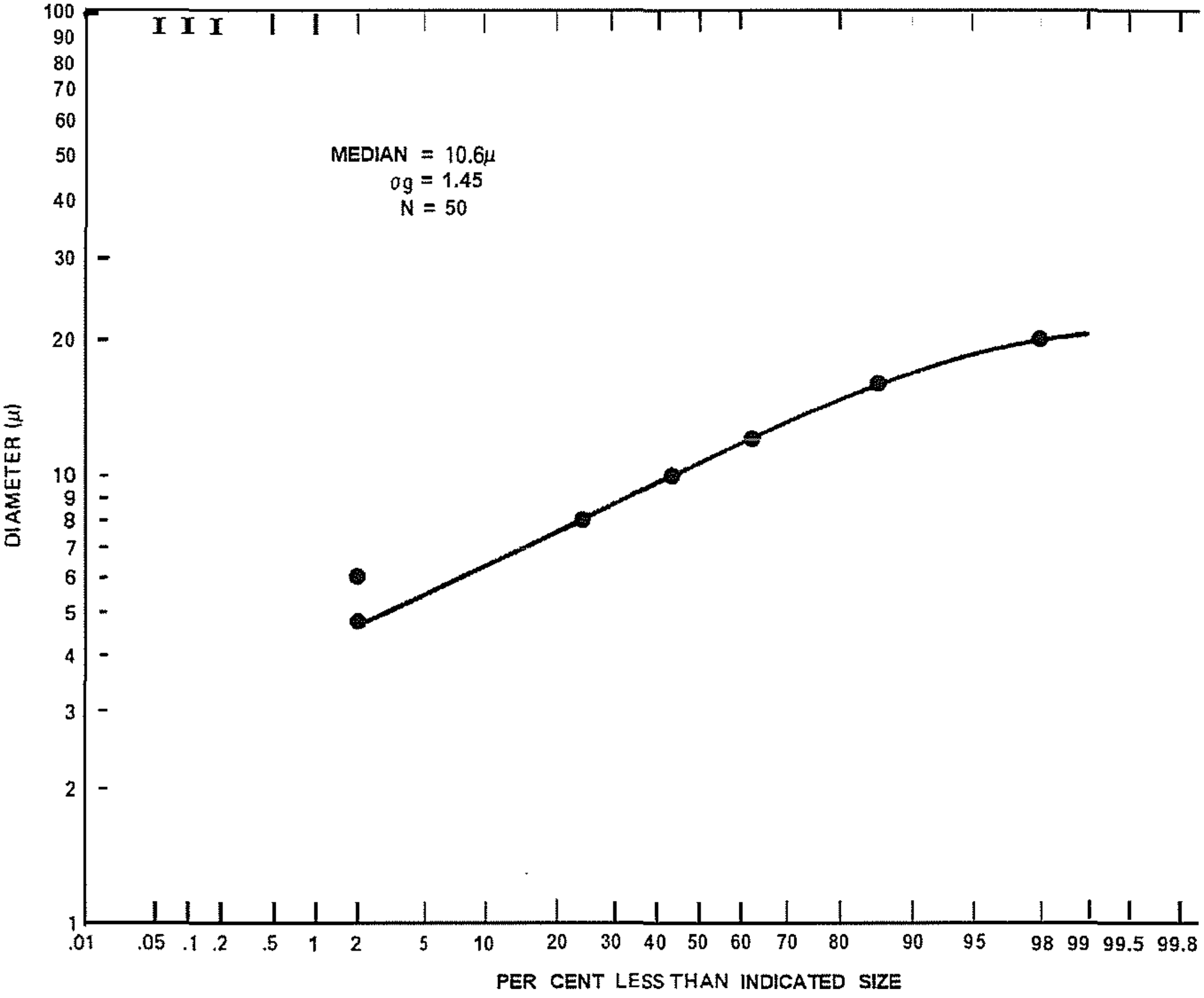

Figure D-Z. Ocean octagonal organisms for class D active particles.

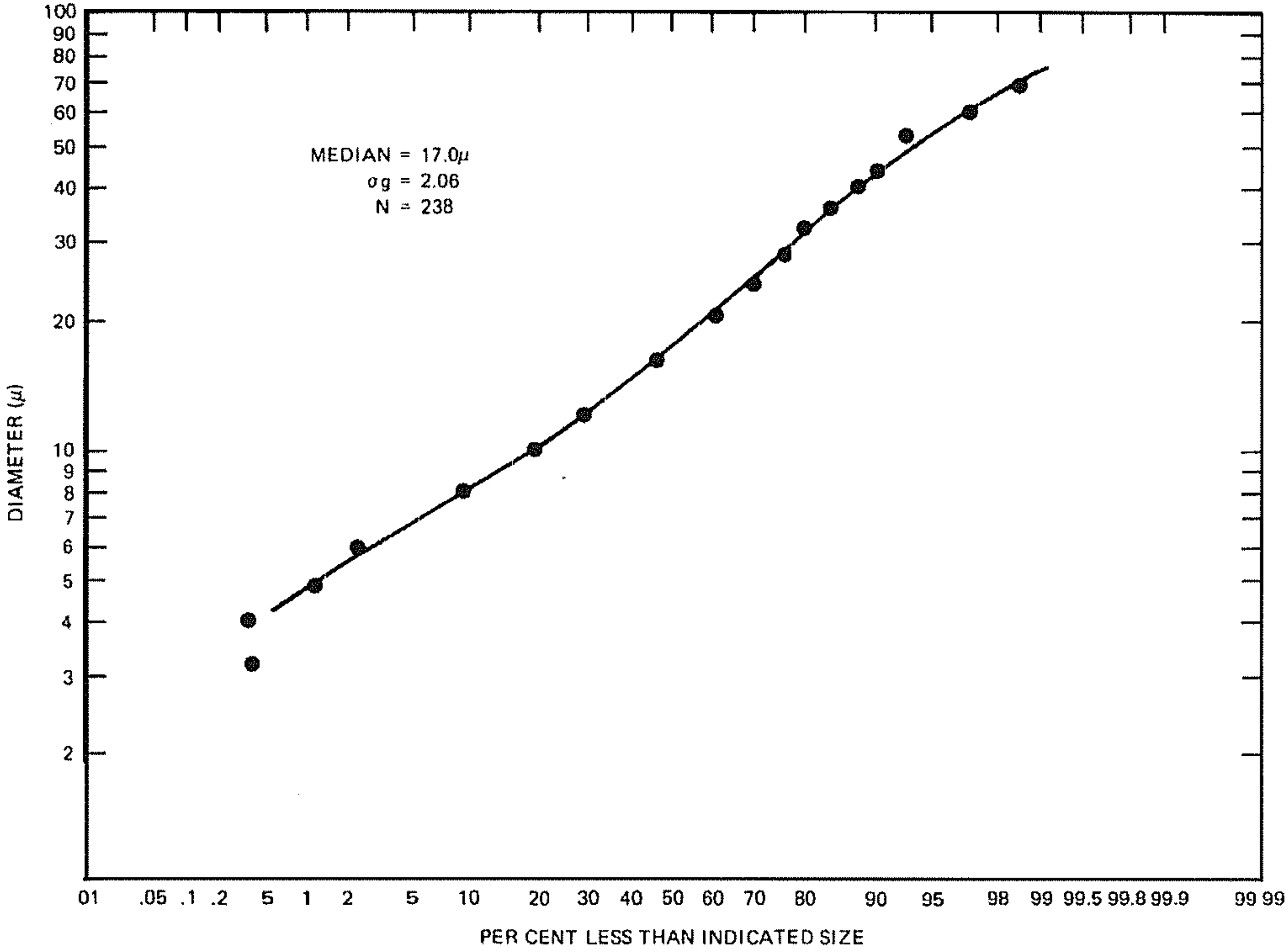

Figure D-1. Gross size distribution for all classes of active particles

Table D-1. Classes of active particles.

A	Discrete, irregular and opaque	41.4% by weight
B	Irregular opaque aggregates	8.2%
C	Distributed areas, opaque to transparent, diffuse boundaries	27.5%
D	Oceanographic organisms, octagonal transparent, sometimes with inclusions	20.5%
E	Organic threads (40-200 microns long)	02.4%

Based on the categorization of particle types in Table D-1, plots are shown of the gross size distribution of all particles and the octagonal organisms in Figures D-1 and D-2, respectively. The color of the particles ranged from yellow through orange, and red to black.

A spectrochemical analysis of the airborne material, irrespective of activity, was made after most of the salt was removed. This analysis indicated the presence of very strong lines of iron and silicon, as well as strong lines of calcium, chronium, magnesium, sodium, and tin. Smaller amounts of silver, aluminum, boron, barium, copper, manganese, nickel, lead, strontium, titanium, and zinc were also observed. It was thought that the large amount of silicon observed in the airborne material was derived primarily from the concrete in the zero barge YC-473 (Reference 5).

D-3 FALLOUT (Reference 5).

As indicated in the previous section, only one percent of the bomb activity was airborne and hence had the potential to be fallout*. Efforts by Project 2.7

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*This value for the fallout is in sharp contrast to nuclear air and surface bursts, in which almost all of the radioactive debris could become airborne and contribute to local fallout.

The complex fluid dynamics produced by WIGWAM resulted in three sources of radiological contamination which are discussed separately in the following sections of this Appendix. Section D-Z describes the airborne activity; Section D-3. discusses the residual fallout; while Section D-4 describes water contamination. These descriptions are followed by Section D-5 which explains the radiological environment on the ships, particularly YAG-39 and YAG-40. Radiological instrumentation for the YAGs and survey aircraft are described in Appendix E.

D-2 AIRBORNE ACTIVITY (Reference 5).

Airborne activity was measured in Project 2.7 aboard the YAG-39, approximately 5 miles downwind from surface zero, by a gamma detector system. At H + 13 minutes, a measurement of 400 R/h was recorded. At H + 21 minutes the radiation level fell to 140 R/h.

Based on a wind velocity of 18 knots, the downwind cloud length was estimated to be 11,000 feet. Given that the cloud rose to the inversion layer at 3,400 feet, and that the turbulent crosswind dispersion equalled the downwind dispersion, the active cloud volume was computed as 3.3 x 10^{11} cubic feet. If this volume was combined with an air sample collected during the high activity period, it was calculated that, at H + 10 days, cloud material activity totalled 0.25 megacuries. An empirical extrapolation using the $t^{-1.2}$ decay law also predicted that the total activity produced by the device would equal roughly 27 megacuries at H + 10 days. Thus the cloud was assumed to contain a maximum of one percent of the total activity.

The physical qualities of the airborne samples, as characterized by both shape and physical form, are shown in Table D-1.

APPENDIX D

WIGWAM RADIOLOGICAL ENVIRONMENT

D-1 INTRODUCTION.

A major goal of Operation WIGWAM was to determine the radiological conditions resulting from a nuclear detonation in a deep-water extended environment distant from all land surfaces. The need for this type of shot is indicated by the following history. In 1954, Shot BRAVO of Operation CASTLE, a surface shot, showed the extent to which a nuclear detonation on or slightly above a land or water surface could contaminate the environment. Another data point, Shot BAKER of Operation CROSSROADS, a shallow underwater shot, showed the contamination caused when a large amount of bottom material interacted with the explosion. In both of these, much of the contamination resulted from interaction with soil or sea bottom.

Because the ranges of prompt neutrons and gamma rays are of the order of a meter or less in water, the prompt neutrons and gamma rays did not directly act as a radiological exposure source to personnel during WIGWAM. Indirectly, however, prompt neutrons acted as a potential cause of radiation exposure by activating ambient materials in the water (e.g., sodium and chlorine).

During the first three seconds after detonation, the radioactive debris were primarily contained within an initial bubble formed by the interaction of thermal energy with the water (Reference 1).

Then, beginning at approximately H + 10 seconds, these gaseous products began to reach the water surface, forming spikes and plumes reaching maximum heights of 900 to 1,450 feet and emerging from an area roughly 3,100 feet in diameter. As the plumes fell back into the water, a large cloud of mist was formed. This was the base surge, at H + 90 seconds, which had a radius of 4,600 feet and a maximum height of 1,900 feet. The visible surge persisted to H + 4 minutes. At H + 13 minutes, a foam ring appeared with a 10,400-foot diameter. The area within this ring probably approximated the extent of the contaminated water.

Thus, the use and interpretation of these values in radiation work require prudent judgment. If possible, exposure to radiation should be kept to a minimum and well below the recommended value. Yet, in the case of particularly valuable benefit to be gained (such as the saving of another's life), a responsible individual may well decide that an added risk is justified, and therefore increase his exposure beyond the standard.

This concludes the discussion of radiation safety standards. In 1955, at the time of Operation WIGWAM, the permissible level was 15 rem per year (see Table C-1). This equals 0.3 rem per week or 3.9 rem for a 13-week period. The AEC accepted this level and instructed its Test Manager to implement it for all participants in the tests. The specific actions and procedures that were taken are the subjects of Chapter 2.

It is important to understand the meaning and significance of these recommended levels, which were not based on a comprehensive scientific understanding of the carcinogenic effects of radiation. Such an understanding did not exist then and does not exist now. If it did, standards could have been extracted directly from scientific facts. What has occurred thus far, however, was that a representative body of informed professionals in medical and relevant scientific areas, such as the ICRP and the NCRP, provided guidance. These bodies reviewed the scientific evidence and then arrived at a recommended value. This was accomplished by somehow balancing the risks due to the lack of complete knowledge against benefits to be gained. These recommended values have been called by various names through the years, such as "tolerance dose," "maximum permissible exposure," and, at present, "radiation protection guide." They are by no means absolute standards in the sense that adherence to them guarantees zero risk or violation of them guarantees harmful effects.

Table C-1 shows how the maximum permissible levels have been reduced through the years. It would be wrong to think that the reductions are based on positive evidence that a previous level was too high. Rather, a statement by the NCRP* explains how the changes come about:

> The changes in the accumulated MPD (maximum permissible dose) are not the result of positive evidence of damage due to use of the earlier permissible dose levels, but rather are based on the desire to bring the MPD into accord with trends in scientific opinion; it is recognized that there are still many uncertainties in the available data and information. Consideration has been given also to the probability of a large future increase in radiation uses.

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*"Maximum Permissible Radiation Exposures to Man," Supp 1. Math. Bur. Std. (US) Handbook 59 (1958), quoted in Reference 18.

Table C-1. Recommended levels of permissible exposure to ionizing radiation - for radiation workers.

Recommended Values		Comments
0.1 erythema dose/y (1R/wk for 200 kV X-ray)	52 R/y	1925: Recommended by A. Mutscheller and R. M. Sievant 1934: Recommended by ICRP and used worldwide until 1950
0.1 R/day (or 0.5 R/wk)	36 R/y	1934: Recommended by NCRP
0.3 rem/wk	15 rem/y	1949: Recommended by NCRP 1950: Recommended by ICRP for total body exposure
5 rem/y	5 rem/y	1956: Recommended by ICRP 1957: Recommended by NCRP for total body exposure
3 rem/quarter	5 rem/y	ERDA Manual, Chapter 0524

(R = roentgen)

Table C-2. Recommended levels of permissible exposure to ionizing radiation - for members of the public.

Recommended Values		Comments
0.03 rem/wk	1.5 rem/y	1952: Suggested by NCRP for any body organ
0.5 rem/y	0.5 rem/y	1958: Suggested by NCRP 1959: Suggested by ICRP for gonads or total body
5 rem/30 y	0.17 rem/y	1958: Suggested by ICRP for gonads or total body
25 mrem/y	0.025 rem/y	1977: Suggested by EPA for any body organ except thyroid*
5 mrem/y	0.005 rem/y	1974: Suggested by ERDA for persons living near a nuclear power plant†

*EPA = Environmental Protection Agency. See EPA, "Rules and Regulations," Federal Register, January 13, 1977 (Reference 17).

†ERDA, now the Department of Energy, DOE. This is the present radiation protection guide of the Nuclear Regulatory Commission.

and, on the other, are low enough to constitute an exceedingly small risk of cancer induction or other harmful effects. The task of defining safe radiation standards has been carried out by several international and national organizations, primarily the International Commission on Radiological Protection (ICRP). which was formed in 1928, and in the United States, the National Council on Radiation Protection (NCRP), which was constituted in 1929 (Reference 15). In a general way, the activities of these bodies consist of reviewing the results of the extensive investigations in the medical area and in radiological physics, assessing these results, and arriving at a consensus on a standard. A short summary of the levels recommended for permissible exposure to ionizing radiation is given in Table C-1 (Reference 15). The values in this table are for radiation workers. For members of the general public, considerably lower values are recommended, which are shown in Table C-2 (Reference 16).

The levels of permissible exposure for radiation workers shown in Table C-1 apply to whole body exposure. Usually such exposure arises from external sources of radiation. But exposure to internal sources of radiation, such as radioactive material inhaled or ingested accidentally, is also possible. Specifying permissible levels for internal exposure is more complex than for external exposure. This is because the activity inhaled or ingested may lodge in different organs of the body, depending on its chemical composition. In addition, the activity may be retained in the body for varying periods of time, and the dose delivered depends on the type of activity (alpha, beta, gamma) that is involved. Thus, while levels for external exposure can in practice be controlled by controlling time spent in measured external radiation fields, levels for internal exposure are controlled by specifying maximum permissible concentrations (MPC) of various radioactive isotopes in air, water, and food that can be inhaled or ingested*.

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*MPCs are specified in 1 CRP Publications No. 2 (1959) and 6 (1962) Pergamon Press, New York.

Except for the following brief remarks, a description of these researches is not given. For a description of the relation of radiation and cancer, the reader is referred to text books on the subject (e.g., Reference 15 and the references contained therein).

Extensive experimentation with animals has demonstrated the reality of cancer induction by radiation. With humans, experimentation is not possible. However, many observations of human experience with radiation have been reported. At one extreme, anyone living on the earth is subject to a natural background of radiation which has existed through the ages. This background radiation is due to cosmic rays from outer space and to the radioactivity of naturally occurring isotopes (mainly potassium-40, uranium-238, and thorium-232) in the terrestrial environment. On the average, a person receives a dose of about 100 millirem (=0.1 rem) per year from natural sources. Inclusion of other sources such as medical exposure results in an estimate of 180 mrem/year average annual whole-body dose in the United States. This dose can vary by a factor of two or more, depending on location, altitude, and the nature of the terrain. It has yet to be established whether this low background dose rate is harmful, or whether, in fact, it is beneficial to man. Further, since the discovery of X-rays, medical use of radiation for diagnostic purposes has added to the radiological dose which the average person receives (i.e., chest X-rays and other man-made sources). It is estimated (Reference 15) that these man-made sources amount to a dose rate of about 80 millirem per year; thus, the man-made contribution nearly equals the natural.

At the other extreme, there have been reported incidents (Reference 15) where individuals have been accidentally exposed to very large doses - over a thousand rads. Such large doses are lethal, survival times being only a few hours or days after the event.

It is believed that between these two extremes, radiological exposure levels can be defined which, on the one hand, are higher than the natural background and thus permit the use of man-made sources for the benefit of mankind, traversed. (This is why these radiations are referred to as "ionizing radiations.")

The quantity usually measured is the exposure, or exposure rate. The instruments are called radiacmeters or dosimeters. They measure the electric current produced by the ionization and are graduated to indicate exposure rate directly on the dial (as the amount of mR/h, for example). Dosimeters integrate the current and indicate exposure rather than exposure rate.

Special films have been developed to measure exposure. These are worn by personnel in a special holder. After use, the film is developed and the degree of darkening is measured. This indicates the exposure by means of a calibration curve reading directly in roentgens. Films and special holders have been developed to measure X-rays, beta rays, and neutrons.

The activity and the dose are not measured directly but are usually deduced from the exposure measurements.

c-5 RADIOLOGICAL SAFETY STANDARDS.

The damaging effects of radiation on human tissue were observed almost coincidentally with the discovery of radioactivity and of X-rays in the late 1800's. Becquerel, the discoverer of radioactivity in uranium, for example, noticed an erythema on his chest as a result of carrying a small radium-bearing sample in his vest pocket. Madame Curie developed radiation burns on her hands from handling a small tube of radium. These effects were reported in 1901 (Reference 14). Since that time, an increasingly extensive body of research has been and continues to be devoted to the investigation of the biological effects of radiation. Among the purposes of these research efforts are the elucidation of the role of radiation both as a causative and as a therapeutic agent in many forms of cancer in humans.

The usefulness of the introduction of the rem as a unit of biological dose was certainly efficacious in the radiation research field as long as it was used in its proper context in comparing biological effects. The extension of the use of the term into general use (where neither the time dependence of the biological end point effect is known for either the baseline X- or gamma radiation or the radiation being compared, nor is the energy deposition spectrum for either radiation known), does nothing but compound the error. Thus, the path from cause to effect is fraught with uncertainties introduced through the translation of a physical measurement to the concept of biological dose.

Even the most meticulous laboratory determinations of radiation cause and effect show wide variations in comparative studies. For instance, RBE values may vary by a factor of at least ten using the same two compared radiations at exactly the same dose rate depending on the mammal being studied and/or the biological end point selected.

In summary, and for purposes of radiological safety, radiation environments are characterized by the following three quantities:

- Activity of its sources - measured in curies
- Exposure - measured in roentgens
- Dose - measured in rads or rems

Techniques and instruments have been developed to measure the quantities discussed above. These techniques and instruments depend on the fact that the radiations deposit energy in their passage through matter. Essentially all energy deposition takes place through the process of ionization, that is, the removal or tearing off of the outer most electrons from the atoms composing the matter cause and effect, not only in biological materials, but in any material. Since it could be postulated that the effect of a radiation was probably proportional to the amount of energy deposited in the irradiated object, the unit roentgen-equivalent physical (rep) was introduced. It was based on the known fact that the energy absorption in one gram of air irradiated by one roentgen of X- or gamma rays is 83 ergs. Thus, one rep was defined as the dose of any radiation that deposits 83 ergs in one cubic centimeter of tissue. Other physical units of dose were proposed and were used by various investigators, but the rep proved to be the most popular in the biological regime. Although based on the energy absorbed in one gram of air exposed to ionizing radiation, the rep is not equal to the energy absorbed per gram or tissue exposed to ionizing radiation. Tissue absorption depends on tissue composition, type of radiation, and the energy of the radiation. For instance, one R dose of gamma rays will result in the deposition of 93 ergs per gram of soft tissue and for corpuscular radiation, the dose is 1.1 rep. Since this phenomenon involves no time of delivery factor, the physical dose term, 1 rep, does not take into account any response that is time dependent.

Another factor considered in establishing units of dose was that the effect could not be solely dependent on the total energy absorbed; instead, it was probably also dependent on the rate of delivery of the energy and the distribution of the energy deposition in the tissue under consideration. Therefore, a new unit of true biological dose was introduced: the roentgen equivalent man (mammal) or rem. This was defined as that quantity of any type of ionizing radiation which, when absorbed in a human body (or a mammal's body), produces an effect equivalent to the absorption of one roentgen of X-radiation or gamma radiation at energies in excess of approximately 50 KeV. This unit is practical because it removes the uncertainties of the effect of radiation energy deposition and the time rate of energy deposition (if the rates are the same for both radiations). Instead, it uses an observable biological end point response. Thus, rem is alloted to physical dose (rep) by the equivalence rem = (RBE) rep. RBE may be called the relative biological effectiveness. The rem can be defined as either rem = rad X RBE or rem = rad X (QF + DF) where QF = a quality factor and DF = a distribution factor.

number of particles or rays traversing a small volume per unit time located in the vicinity of the source. The source establishes a radiation field around it.

The exposure rate is defined as the strength or intensity of this radiation field at the specified location. It is measured in a unit known as the roentgen*, and is used for beta and gamma radiations. The intensity of a radiation field of beta or gamma radiation is thus said to be so many roentgens per second or other unit of time. For alpha particles or neutrons, a different measure is often used. A measure is taken of the number of particles crossing a unit area per unit time at the specified location. This is called the flux. The exposure rate is then said to be so many roentgens per unit time (for beta and gamma radiation), or so many particles per unit area per unit time (for neutrons and alpha radiation).

If a piece of matter is placed in a radiation field, the radiation traverses it and deposits energy by the process of ionization. (Ionization consists of tearing off one or more electrons of the atoms which compose the matter traversed.) The amount of energy deposited per unit mass of matter is called the absorbed dose, or simply dose. It is measured in units called rads; one rad is the absorption of 100 ergs of energy per gram of matter. An exposure to one roentgen of gamma rays will, as noted, deposit about 1 rad of dose in human tissue.

As radiation sources become more numerous and with the development of the controlled fission process leading to weapons, reactors, and radioactive isotope production, the units of dose commonly used become totally inadequate in equating

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*After W. Roentgen, discoverer of X-rays. A technical definition of the roentgen is: "that quantity of X- or gamma radiation such that the associated corpuscular emission per 0.001293 grams of air, dry, 0° C, 760 mm of Hg, produces in air, ions carrying one electrostatic unit of quantity of electricity of either sign." (Reference 13)

The source of radiation causes certain levels of radiation to exist in the space around it. A sufficient amount of exposure to this radiation is known to have biological effects. Since some of these effects are known to be harmful to humans, it is necessary to control an individual's exposure in any activity involving proximity to radioactive sources. Before discussing the potentially harmful effects further, it is necessary to define the quantities involved and the units used in measuring these quantities.

C-4 UNITS AND QUANTITIES IN RADIOLOGICAL SAFETY.

The three important quantities or concepts in radiological safety are activity, exposure, and dose. These are technical terms and are defined below. For the sake of clarity in this report we have used the basic units (e.g., roentgen and rep) which were in common use at the time of Operation WIGWAM, rather than converting them to the presently used rad or rem units. (The conversion would not change quantities by more than 12 to 15 percent since 1 rep = 0.88 rads.) After the definitions, their use is illustrated in a simple example typical of the Rad-Safe operations at WIGWAM.

The activity of a source is the number of nuclear disintegrations occurring per unit time. It is measured in curies,* one curie (symbol Ci) being the disintegration of 3.7 x 1010 nuclei per second. At the time of its definition, the curie was believed to be the disintegration rate of one gram of radium.

Each disintegration produces one or more types of radiation (alpha, beta, neutron, gamma) which travel away from the source. Thus, there will be a certain

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*After Marie Curie, the discoverer of radium.

Once the plume of water and spray falls back into the water, a large doughnut-shaped cloud, moving rapidly outward from the column, develops. This is called the base surge. The importance of the base surge lies in the fact that it is likely to be highly radioactive because of the fission (and other) residues present, either at its inception or dropped into it from the radioactive cloud. The length of time the base surge remains radioactive depends upon the energy yield of the explosion, the burst depth, and the nearness of the sea bottom to the point of burst.

In Shot WIGWAM, the first deep-water nuclear detonation, the bubble that was created with the 30 KT detonation (2,000 feet below the surface of the Pacific Ocean) continued to pulsate and rise for three complete cycles; then enough steam condensed to make additional pulsations unlikely. During the pulsation and upward motion of the bubble, the water surrounding the bubble acquired considerable momentum and eventually broke through the surface with a velocity which was estimated at 200 miles per hour. This created a large spray dome that turned into a plume and formed the base surge.

Thus, the sources for the radiological environments of Operation WIGWAM were the following:

- o Airborne activity
- o Residual Fallout
- 0 Water contamination - Because the ranges of prompt neutrons and gamma rays are a meter or less in water, there was no prompt radiation exposure to personnel during WIGWAM. Indirectly, however, prompt neutrons acted as a potential cause of radiation exposure by activating ambient materials in the water (e.g., sodium and chlorine).

heating of the body of water. Depending upon the depth of the explosion, some of the thermal and nuclear radiations will escape, but the intensities will generally be less than for an air burst. However, the radiation emitted after the first minute is of considerable significance since large quantities of water in the vicinity of the explosion will be contaminated with radioactive fission products.

Certain characteristic phenomena are associated with an underwater nuclear explosion, but the details vary with the energy yield of the weapon, the distance below the surface at which the detonation occurs, and the depth and area of the body of water. A brief description of these phenomena follows. For a more complete description see Reference 12.

In an underwater explosion, the hot gas bubble produced a few seconds after detonation initiates a shock wave. The intersection of the shock wave with the water surface produces the effect of an expanding ring of darkened water called a "slick." Following closely behind the dark region is a white circular patch known as the "crack", most likely caused by reflection of the water shock wave at the surface.

Immediately following the appearance of the crack, and prior to the formation of the condensation or "Wilson" cloud, a column of broken water and spray, called the "spray dome," is thrown up over the point of burst. The total time of rise and the maximum height depend upon its depth below the surface. If the depth of burst is not too great, the hot gas bubble remains essentially intact until it rises to the surface of the water. Part of the shock wave passes through the surface into the air, where due to the high humidity, a condensation cloud is formed. As the pressure of the bubble is released, water rushes into the cavity and is thrown up as a hollow cylinder of spray called the "plume." The radioactive contents of the bubble are vented through this hollow column and may form a cauliflower-shaped cloud at the top.

either positively or negatively charged electrons with small mass but high kinetic energy. Beta rays have a longer range than alpha rays. They can penetrate to a depth of a centimeter in human body tissue. Beta radiation is emitted copiously by the fission products of a nuclear weapon and by solar radiation products interacting with our environment. Beta particles produce ionization in matter.

o Neutron Radiation - Neutrons are uncharged nuclear particles produced in natural solar processes and emitted in nuclear fusion and fission reactions. Neutron radiation produces ionization in its passage through matter. Neutrons emitted by exploding nuclear weapons have long ranges. Once released, the neutrons travel several hundred yards in air and penetrate a few feet in soil.

o Gamma Radiation - Gamma radiation is comprised of electromagnetic waves, not particles. It ionizes matter and is very penetrating. In this respect, it is very similar to neutron radiation. Gamma radiation is emitted by the nuclear weapon and by the fission products in fallout.

C-3 RADIOLOGICAL ENVIRONMENTS IN UNDERWATER NUCLEAR TESTS.

A nominal nuclear fission weapon has an explosive yield equivalent to 20 kilotons of TNT. This corresponds to the consumption, via fission, of about 1.1 kilograms of uranium or plutonium, depending on which isotope is used. It results in the production of somewhat less than 1.1 kilograms of fission products. (The difference in mass is what has been converted into the energy of the explosion according to Einstein's equation, $E = mc^2$.)

In a subsurface burst, most of the shock energy of the explosion appears as underwater shock, but a certain proportion, which is less the greater the depth of the burst, escapes and produces air blast. Much of the thermal radiation and the initial nuclear radiation will be absorbed within a short distance of the explosion. The energy of the absorbed radiations will merely contribute to the

The aspect of fission which leads to radiological hazards is the production of two fission fragments for each fission event. The fission products, or fragments, are highly radioactive. They decay to stable isotopes by emitting beta particles and gamma radiation. There are about 40 different ways in which a nucleus can split in fission. Most of the resulting 80 types of fragments are radioactive and decay through about three steps before reaching a stable nucleus. Half-lives can vary from a few tenths or hundredths of a second to many hundreds or even thousands of years. Some 200 different radioactive isotopes of 36 light elements, from zinc to terbium, have been identified among the fission products.

Fusion reactions, on the other hand, do not produce the copious amounts of radioactive products that fission reactions do. The fusion reaction has been operating most efficiently in our sun for millions of years and the products of this reaction have been radiating our environment for millennia. Naturally radioactive materials are present all over the surface of the earth and contribute to the background levels which are found everywhere in varying degrees.

This brief sketch of nuclear physics is concluded by listing the types of <u>nuclear ionizing radiations</u> and giving some of their properties. Once established in the environment, these ionizing radiations are the agents responsible for radiological hazards.

- Alpha Radiation - Alpha radiation consists of nuclear particles (helium nuclei) which have very short ranges in matter; e.g., they will not penetrate human skin, or a piece of paper. These particles are emitted by heavy isotopes such as uranium and plutonium. Alpha particles are relatively massive, are electrically charged, and have large amounts of kinetic energy. They deposit energy in the matter they traverse by ionization.

- Beta Radiation - As is the case with alpha radiation, beta radiation is particle (electron) radiation. These can be

APPENDIX C

CONCEPTS OF RADIOACTIVITY AND RADIATION PROTECTION

(Continued)

Two more topics from nuclear physics must be briefly mentioned before explaining the origin of the radiological hazards of nuclear weapons. The first topic is the nuclear reaction known as fission. In this reaction, a neutron enters a heavy nucleus and the resulting excitation causes the nucleus to split into two more or less equal fragments; that is, to fission. In addition to the two nuclear fragments, two or three neutrons and gamma rays are also emitted. The fission process occurs in only a few heavy isotopes. The predominant isotopes are uranium-235, an isotope occurring naturally in uranium ores, and plutonium-239, a man-made isotope produced from uranium-238 in nuclear reactors.*

The significant feature of the fission process is the production of more neutrons. Under suitable conditions, the production of more neutrons induces more fissions and more neutrons, etc., in a continuing sequence of successive generations known as the nuclear chain reaction. This is what makes fission nuclear weapons possible. For further details on the chain reaction, see Reference 11.

The second topic from nuclear physics is the nuclear reaction known as fusion. If a mixture of certain light isotopes are combined at very high temperatures and pressures, the nuclei fuse together. Examples of this are deuterium (heavy hydrogen) and tritium. The products of fusion are isotopes of helium and hydrogen, high-speed neutrons and energy. The intense temperatures (tens of millions of degrees) and pressures (thousands of atmospheres) required for the fusion reaction are usually provided by the fission reaction. The resulting weapons, called thermonuclear weapons, utilize both the fission and fusion reactions.

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*All the elements beyond 92 (uranium), the so-called transuranics, are man-made and all are radioactive.

one of its neutrons into a proton and emitting an electron. In this instance, the electron is called a beta particle or a beta ray to differentiate it from the orbital electrons. It flies away from the atom with relatively high energy. The beta particle leaves behind a nucleus with an atomic number of 2, one neutron, and an atomic weight of 3 (Z + N = A). The outcome is helium 3, a stable isotope of helium.

Most of the naturally occurring elements have several stable isotopes. At the heavy end of the series of the 9.2 elements, it has been found that beyond bismuth (Z = 83) there are no stable isotopes; all are naturally radioactive. Uranium (Z = 92) occurs naturally • mainly as the radioactive isotope with an atomic weight of 238. The reason uranium -238 is observed at all is that the half-life is very long. Its half-life of four and one half billion years, is comparable to the age of the earth. Uranium-238 decays by emitting an alpha particle. The alpha particle is a closely bound group of four nucleons, 2 protons, and 2 neutrons. It is, therefore, a helium nucleus. Inasmuch as both Z and N have been reduced by two, there is left behind a nucleus of a different element called thorium. This type of radioactive decay is called alpha decay and it is typical of the heavy elements.

Thus far, two types of nuclear radiation have been discussed: alpha radiation from alpha decay, and beta radiation from beta decay. In addition, there is a third type called gamma radiation. Many radioactive nuclei emit radiation known as gamma rays. Alpha and beta radiations are particles and their emission results in the transformation of the decaying element into another element. Gamma radiation is in the form of electromagnetic energy similar to radio waves, X-rays, and light waves. Gamma radiation is one way a nucleus can radiate energy without transforming into another type of nucleus. However, gamma radiation usually is emitted during nuclear transformations along with beta particles.

electrons move around this core. Hydrogen, element 1 and the lightest of the naturally occurring elements, has one proton as its nucleus and one electron revolves around it. Like all atoms, this atom as a whole is electrically neutral. If a neutron is added to the hydrogen nucleus, the outcome is an atom of deuterium, or "heavy hydrogen." Deuterium is an "isotope" of hydrogen; that is, its nucleus has the same number of protons as the nucleus of hydrogen, but a different number of neutrons. By adding more protons and neutrons to the nucleus and more electrons in orbits, heavier and heavier atoms are built. Eventually, the last naturally occurring element (uranium, element 92) is reached. It has a nucleus of 92 protons and 146 neutrons, and 92 electrons circulating in a cloud of orbits around the nucleus. In effect, the resulting array of different kinds of atoms is a concise picture of all the different elements. It has several interesting properties.

The number of protons in the nucleus is called the atomic number (symbol Z) of that nucleus or element. The number of protons, Z, plus the number of neutrons, N, is called the atomic weight* (symbol A). Thus $Z + N = A$. The number of elements corresponds to the number of different values for Z; that is, the series 1, 2, 3, . . ., 92. For a particular value of Z only one or a few values of N give stable nuclei that occur in nature. Thus, for $Z = 1$ (one proton, hydrogen), only two values of N (no neutron or only one neutron) are naturally stable. Thus, another combination, $Z = 1$ and $N = 2$, is not naturally stable. It is a form of hydrogen called tritium which is unstable; that is, it is radioactive. This means that it gradually decays (half-life about 12.5 years†) by converting

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*Also referred to as the number of nucleons.

†The half-life of a given radioactive isotope is the time in which the activity of the isotope is reduced by one half.

APPENDIX C

CONCEPTS OF RADIOACTIVITY AND RADIATION PROTECTION

C-1 INTRODUCTION.

This appendix reviews the basic facts about nuclear radioactivity and radiation, and their production by nuclear weapons. In addition, it notes the biological effects of these radiations and outlines briefly the development of radiation safety criteria which have been set up to protect humans from the hazards of radiation. Thus, this appendix serves as an introduction to Chapter 2, which describes the specific radiological safety (Rad-Safe) activities, procedures, safety criteria, etc., that were implemented in Operation WIGWAM for the protection of all participants.

c-2 TYPES OF RADIATION.

It is well known that all matter in its great variety of forms is composed of various proportions of a relatively small number of basic constituents known as the elements.* The smallest part of an element that can exist while retaining the characteristics of that element is called an atom.

In the simplest model, all atoms are composed of combinations of only three types of elementary particles: the proton, the neutron, and the electron. The proton and neutron are about the same mass, which is some 2,000 times greater than the mass of the electron. The proton has a positive unit electrical charge, the electron a negative unit electrical charge, and the neutron, as its name implies, is electrically neutral. The protons and neutrons, collectively referred to as the nucleons, make up what is called the nucleus of the atom. The nucleus is the small central core where most of the mass of the atom is concentrated. The

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*For more detail than the brief summary given here, see any text on elementary nuclear physics such as Reference 11.

APPENDIX B

WIGWAM SHIPS, AIR UNITS AND STAFF ELEMENTS

(Continued)

	Number of Participants
Surface Support Unit	
USS MOCTOBI (ATF-105) Fleet Ocean Tug	69
USS CHANTICLEER (ASR-7) Submarine Rescue Ship	96
YFNB-13, SQUAW-13, YFNB-Large Covered Lighter	Unmanned
USS HITCHITI (ATF-103) Fleet Ocean Tug	76
USS BOLSTER (ARS-38) Submarine Rescue Ship	91
YFNB-12, SQUAW-12, YFNB-see above	Unmanned
USS TAWASA (ATF-92) Fleet Ocean Tug	73
YC-473 (Open Lighter, Weapons Barge)	Unmanned
USS CREE (ATF-84) Fleet Ocean Tug	68
USS RECLAIMER (ARS-42) Submarine Rescue Ship	78
YFNB-29, SQUAW 29, YFNB-see above	Unmanned
USS FT. MARION (LSD-22) Landing Ship, Dock	279
USS COMSTOCK (LSD-19) Landing Ship, Dock	241
USS MARION COUNTY (LST-975) Landing Ship, Tank	100
USS MORGAN COUNTY (LST-1048) Landing Ship, Tank	96
USS BUTTERNUT (AN-9) Net Laying Ship	42
25-LCM's Landing Craft, Mechanized	
4-XLCM's Landing Craft, Mechanized	230 (total)
	1,539
Land-Based Air Support	
FASRON-110 (P4Y Aircraft)	2
137th Mapping and Charting Squadron (USAF) (RB-50 Aircraft)	
4901 Air Base Wing (USAF) (C-54 Aircraft)	15
	17
Staff Elements	
Commander Destroyer Squadron 13 and Staff	Included in surface patrol unit
Commander Tug Squadron ONE and Staff	Included in surface support unit
OVERALL TOTAL*	6,097

*Does not include personnel in Table 1-1.

APPENDIX B

WIGWAM SHIPS, AIR UNITS AND STAFF ELEMENTS

	Number of Participants
Flagship Unit	
USS MT. MCKINLEY (AGC-7) Amphibious Force Flagship	552
USS CURTISS (AV-4) Seaplane Tender	573
	1,125
Scientific Unit	
USS GEORGE EASTMAN (YAG-39) Converted Liberty Ship	48
USS GRANVILLE S. HALL (YAG-40) Converted Liberty Ship	48
USS MOLALA (ATF-106) Fleet Ocean Tug	76
M/V Horizon (Converted ATF) Ocean Tug (Scripps)	18
M/V Spencer F. Baird (Scripps)	16
M/V Paolina-T (Converted ATA) Auxiliary Ocean Tug (Scripps)	5
M/V T-Boat (Scripps)	10
	221
Surface Patrol Unit	
USS BLUE (DD-744) Destroyer	266
USS ALFRED A. CUNNINGHAM (DD-752) Destroyer	268
USS FRANK E. EVANS (DD-754) Destroyer	269
USS MCKEAN (DDR-784) Radar Picket Destroyer	256
USS WALKE (DD-723) Destroyer	261
USS O'BRIEN (DD-725) Destroyer	285
USS HARRY E. HUBBARD (DD-748) Destroyer	258
USS ERNEST G. SMALL (DDR-838) Radar Picket Destroyer	265
	2,128
Carrier Air Support Unit	
USS WRIGHT (CVL-49) Small Aircraft Carrier	974
Air Units: HMR-362 (Marine HRS-3 Helicopters)	49
VS-21 (AF-2S Aircraft)	26
VC-35 (AD-5N Aircraft)	18
	1,067

APPENDIX A

28 January 1978

MEMORANDUM FOR THE DIRECTOR, DEFENSE NUCLEAR AGENCY

SUBJECT: DoD Personnel Participation in Atmospheric Nuclear Weapons Testing

The Defense Nuclear Agency is designated as the DoD executive agency for all matters pertaining to the participation of DoD personnel in the atmospheric nuclear weapons test program.

As the executive agency, you are responsible for accomplishing the following specific tasks and for any others that may develop:

--Develop a history of every atmospheric nuclear event that involved DoD personnel

--Identify the radiation monitoring control policies, procedures, and requirements that were in effect

--Assemble a census of personnel at each event. Identify their location, movements, protection, and radiation dose exposure

--Make this information available for scientific review and appraisal

--Handle public affairs matters in cooperation with the office of the Assistant Secretary of Defense (Public Affairs)

--Handle Congressional Affairs matters in coordination with the Office of the Assistant to the Secretary of Defense for Legislative Affairs

For matters pertaining to this assignment you are authorized to:

--Conduct direct liaison with other government departments and agencies

--Task the Military Departments and other elements and components of the DoD

Please provide this office progress reports on a monthly or more frequent basis.

Assistant Secretary of Defense
Manpower, Reserve Affairs and Logistics A-3

5-4 REPORTED PERSONNEL PARTICIPATION AT WIGWAM.

Participation of DoD military and civilian personnel in Operation WIGWAM is summarized in Table 5-3. The listing of personnel by assigned unit contains the names of persons as reflected by records originally maintained by NRDL.

5-5 SUMMARIES OF PERSONNEL EXPOSURE DATA.

Appropriate statistical summaries of the WIGWAM census personnel exposure data are being published in a supplemental volume.

Table 5-3. WIGWAM participants.

TASK UNIT		FUNCTION	NUMBER OF PERSONNEL
7.3.0	FLAGSHIP	Command and Control; Visitors/Observers	1,171
7.3.1	SCIENTIFIC	Weapon preparation, detonation, effects measurement; environmental surveys; radiological safety.	622
7.3.2	CARRIER AIR SUPPORT	Air search and rescue; antisubmarine patrol; control of air space in operational area; sampling, survey, helicopter lift, as required.	1,067
7.3.3	SURFACE PATROL	Surface search and rescue; escort duty; antisubmarine patrols.	2,128
7.3.4	SURFACE SUPPORT	Transport, towing; wire recovery; rigging and salvage; small boat pool	1,539
7.3.5	LAND BASED AIR SUPPORT	Air patrol; photography, sample collection; surveys.	17
		TOTAL*	6,544

*Includes 447 participants associated with various agencies (Table 1-1) plus 6,097 participants operating the ships as listed in Appendix B.

Table 5-2. Data Sources in NTPR Roster of DoD Participants.

SOURCE	IDENTIFICATION DATA	DOSE DATA
NRDL	X	X
REECo	X	X
Public	X	
GSA Repositories		
-Personnel Records (Separated)	X	
-Medical Records (Separated)		X
VA		X
DASIAC	X	
Armed Services		
-Morning Reports, Diaries, Muster Rolls,-Deck Logs	X	
-Orders	X	
-Discharge Records	X	
-Personnel Records (Active duty)	X	
-Medical Records (Active duty)		X
-Administrative Service	X	
-Weapons Test Reports, Rosters	X	
-Reserve Affairs	X	X
Other Sources		
-Internal Revenue Service	X	
-Federal Bureau of Investigation	X	
-Department of Energy	X	

The sources described above provide information of general applicability to the DoD participants in Operation WIGWAM. In addition, the Armed Services have specific sources, applicable to their particular branch:

- Morning reports, unit diaries, muster rolls, and daily ships' deck logs. Those sources provide identification data on personnel assigned to participating units, absent from their home unit, or in transient status for the purpose of participating in a nuclear weapons test.
- Official travel or reassignment orders provide further identification information relative to transient or assigned personnel participating in the nuclear weapons tests.
- Discharge records are maintained by all services and aid in identification.
- Military personnel records for individuals still on active duty provide information relative to those individuals' assignments to participating units or attendance in transient status at the nuclear weapons test.
- Medical records for active duty personnel provide exposure or dose information in some cases.
- Each service also has Adjutant General personnel concerned not only with the administration of the services but also with the maintenance of records and the preservation of unit histories for units throughout that service.
- After action reports, security rosters, and vehicle loading rosters related to the military exercises provide identification information on participants.
- The Services reserve personnel activities provide both identification information on participants, who may still be carried on active or inactive reserve roles, and exposure or dose information from medical records of those individuals.

Table 5-2 summarizes NTPR data sources which relate to the identification of personnel and the determination of dose.

personnel separated from the Services. These records are required to substantiate an individual's eligibility for medical or dental care, as well as any disability compensation claims and other authorized veteran benefits. The VA gets its files from the NPRC in St. Louis and only retains an individual's file while a case is under consideration. However, the VA does maintain a master computer file, BIRLS, which can provide information on cases previously considered.

6. DoD Nuclear Information and Analysis Center.

DASIAC (formerly Defense Atomic Support Information and Analysis Center) provided information relative to identification of individuals and military units by identifying and reviewing a large body of reports available or listed in a bibliographic data base.

7. Official Reports.

Some personnel identification and exposure information is contained in the following official reports written relative to Operation WIGWAM.

- Scientific Director's Summary Report provides some generalized information on the number of participants, but no specific data relative to exposure
- Commander, Test Group 7.3, "Operation Plan 1-55" provided operation data and some generalized exposure data but no delineation of exposure by individual.
- The NRDL Rad-Safe Report provides some exposure information but no individual identification of exposure data. The source includes ocean contours, residual radiation measurements, and some non-specific identification data.
- Weapon Test reports (WT's) provide detailed information about the radiological hazards to personnel on board ships traversing a zone of water contaminated by a subsurface nuclear detonation. The information was developed through consideration of the size, shape, location, and radiation characteristics of the contaminated areas as a function of time. The reports include some exposure data, but provide no specific identification information.
- The AFSWP Operational report provides summaries which highlight AFSWP participation. Some exposure data are included but no specific identification information is available.

summarized computer tapes which are indexed for retrieval, or REECo has incorporated NRDL's dose records into the master file.

3. General Public.

Information from the general public contributed to the identification of participants. Starting in February 1978, the public was invited, via repeated media announcements, to call in by toll-free telephone to the Defense Nuclear Agency describing their participation in nuclear tests. Over 40,000 responses have been received. The public has provided identification information but not exposure data.

4. The General Services Administration.

Medical records and personnel records maintained in storage by GSA have been used as a source for identification of individuals and for dose information. GSA operates the National Personnel Records Center (NPRC), located in St. Louis, Missouri, which is the main repository for medical and personnel records of individuals separated from the Armed Services. The determination of exposure and dose information from Army medical records was hampered by the fact that, in July 1973, a fire at NPRC destroyed some 13 to 17 million records - about 80 percent of the medical records for Army personnel discharged between 1 November 1912 and 31 December 1959, and for Army Air Corps/Air Force personnel discharged between 31 December 1947 and 31 December 1963. The GSA also operates records storage facilities which provided some operational data, principally supporting identification information with only limited dose information. A few of these repositories are listed below:

- o Laguna Niguel, California
- o San Bruno, California
- o Suitland, Maryland.

5. The Veteran's Administration.

The VA is a source of some exposure or dose information, in that it maintains on file copies or originals of medical and/or personnel records for

- Bioassay - This record indicates sources of radiation exposure other than external. If bioassay studies were conducted, the sources were reflected in urine or blood analysis and fall into generic or specific categories.

If bioassay data existed for a participant, a bioassay record was created.

Each participant is represented by all available data. Thus, representation begins with series summary data and is followed by event, exposure, and bioassay data, if any. If an individual participated in more than one series, there are indicators directing the researcher to a new series record. Individuals who participated sometime during a series, but who could not be identified with a specific event or for whom an event exposure could not be determined, have a series record without any associated event record.

5-3 DATA SOURCES.

Basically, the NTPR Roster of DoD Participants maintains information which pertains to:

- Identification data
- Exposure data.

To develop this Roster, the Services obtained information from a number of sources. Primary sources of data input follow:

1. Naval Radiological Defense Laboratory.

NRDL was located in San Francisco. NRDL processed and stored film badge records, and was a principal source of dosimetry data. When NRDL was disestablished in 1969, records were sent to the GSA repository in San Bruno, California.

2. Reynolds Electrical and Engineering Company.

REECo in Las Vegas maintains a master file of dosimetry data for the Department of Energy. Most of these data are either on microfilm, or on yearly accommodate specific circumstances. The major categories of the elements can be generally described as follows:

- o Identification data which include a complete spelling of surname, first and middle names when known, date of birth, room for two social security numbers in the case of conflicting numbers which cannot be resolved, and room for up to four service serial numbers in event of change in status, etc.
- o Participation data which contain information on the individual's service or other affiliations, unit and rank at the time of test series, event, and a key to denote participation in more than one series. (Those individuals participating in more than one series have a complete record for each of the series.)
- o Radiation data which contain the radiation exposure received along with information regarding the period of exposure, and any bioassay data including comments and narrative data as well as various assay results. Radiation dose includes gamma, beta, fast neutron, and thermal neutron dose information. (See Appendix C for radiation type, description, and the units of measurement.)
- o Source data which describe in code the sources of information for each data element appearing in the above three categories of the record. In the case of radiation data, these codes also include a notation to indicate exposures which are estimated or calculated rather than measured by film badge, etc. These sources are described in Section 5-3.

Using the data elements described above, the structure of the Roster incorporates the following four methods of data organization which have been organized according to the expected condition of data available.

- 0 Series - The series record tape reflects accumulated radiation data covering the individual's entire involvement in that series.
- o Shot - The shot record reflects the radiation data when it was possible to determine an individual's participation in a shot and to associate a discrete exposure to that shot.
- o Exposure Reading - The exposure reading record reflected the most discrete exposure information available by research. In some cases, the reading may contain a series summary as reported by REECo while other records may reflect individual badge readings. The sum of individually recorded exposures should equal the exposure reported in the summary record for the series; it may not, however, if all individual exposures have not been recorded.

Table 5-1. NTPR Roster Data Elements.*

NTPR ROSTER DATA ELEMENTS*

IDENTIFICATION DATA

LAST NAME
FIRST NAME
MIDDLE NAME
SOCIAL SECURITY NO.(S)
DATE OF BIRTH
SERVICE SERIAL NO.(S)

PARTICIPATION DATA

SERIES
EVENT
SERVICE (OR OTHER AFFILIATION)
RANK
UNIT
MULTIPLE SERIES DESIGNATION

RADIATION DATA

DATE OF ARRIVAL AT TEST SITE
DATE OF DEPARTURE FROM TEST SITE
GAMMA EXPOSURE
BETA EXPOSURE
FAST NEUTRON EXPOSURE
THERMAL NEUTRON EXPOSURE

BIOASSAY DATA

NARRATIVE

SOURCE DATA

FOR EACH DATA ELEMENT

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*These elements will be Included as available.

CHAPTER 5

PERSONNEL DATA BASE

5-1 INTRODUCTION.

The Director of the Defense Nuclear Agency (DNA) was tasked in an Assistant Secretary of Defense memorandum dated 28 January 1978 to compile a census of individuals who participated in atmospheric nuclear weapons tests between 1945-1962 and their corresponding exposures. Specifically, one of the tasks *was* to "assemble a census of personnel . . . identify their location, movements, protection, and radiation dose exposure." (Appendix A)

Radiological safety and activities are discussed by unit in Chapters 2 and 3, respectively. A separate volume, the Operation WIGWAM Roster of DoD Participants, contains information on individuals and may be released only under the provisions of the Privacy Act. This chapter discusses the format of the Nuclear Test Personnel Review (NTPR) Roster of DoD Participants and describes both the sources of information and the methodology used during data collection.

5-2 DESCRIPTION OF NTPR ROSTER OF DoD PARTICIPANTS.

The NTPR Roster of DoD Participants is designed to meet the needs of individual participants, the scientific community, DoD, and other Government organizations. Corrections or changes to the Roster are maintained by DNA Headquarters. The Roster contains, to the extent obtainable, a census of participants and their associated radiation exposure data which have been verified by the military department or agency responsible for that participation. The data may be periodically extended as new information is discovered.

The personnel identification elements and radiation exposure elements of the Roster, developed by numerous Government organizations after extensive review, are indicated in Table 5-1. In order to provide a thorough, coherent effort, provision was made for many data elements, though not all elements were assured an input. Some data elements are self-explanatory, but others are necessary to

The estimated maximum value of inhaled activity is:

Max Activity = B x At x C = .025 μCi

where B = breathing rate of standard man
= 8.3×10^{5} cm^{3}/hr (ref 11)
At = 1 hr (ref 12)
C = 3×10^{-8} $\mu Ci/cm^{3}$ (ref 4)

MPBB* I^{131} - 0.7 μCi/body

This is a factor of 100 higher than could have been received. When factors such as retention are considered, it can be seen that the inhalation hazard was below the MPBB.

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*MPBB = Maximum Permissible Body Burden, per ICRP recommendations.

4-6. INTERNAL INHALATION RADIATION DOSES.

Because of the Rad-Safe organization and protective systems, the probability of the participants receiving an internal radiation exposure was limited to two instances. These instances occurred in the downwind direction on the YAG-40 and the M/V Horizon.

From Reference 4 it appears that the maximum level of beta and gamma airborne contamination recorded, $3x10^{-8}$ microcuries per cubic centimeter ($\mu Ci/cm^3$), was measured by the YAG-40 between H and H + 1 hour and at roughly the same time the Horizon recorded a value of $2x10^{-8}$ $\mu Ci/cm^3$.

Because WIGWAM was a deep underwater shot, the activity was extremely fractionated and its downwind distribution was limited to the base surge. It was estimated that most of the activity remained in the water patch and only a small amount of activity was entrained in the base surge. This amount of activity was composed mainly of the gaseous fission products of which iodine is the most abundant element and I^{131} is one radioisotope. Therefore, to be conservative in our estimate of inhalation hazard, the Maximum Permissible Concentration (MPC) of I^{131} for inhalation will be used in the calculations. The MPC air for I^{131} based on continuous occupational exposure is 4x10-9 @i/ml.* Other factors for consideration are the maximum 1-hour cloud passage over (stay time) the ships in the base surge (Reference 12) and the degree of protection afforded the participants. In the case of the YAG-40, all participants were in a shielded compartment with a filtered air supply. Therefore, the inhalation concentration activity would have been considerably below the maximum reported value of $3x10^{-8}\mu Ci/cm^3$ because of filter efficiency, and even at this value, the inhaled activity would have been, at most, comparable to the allowable daily 8-hour occupational exposure.

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* Reference ERDA MC 0524.

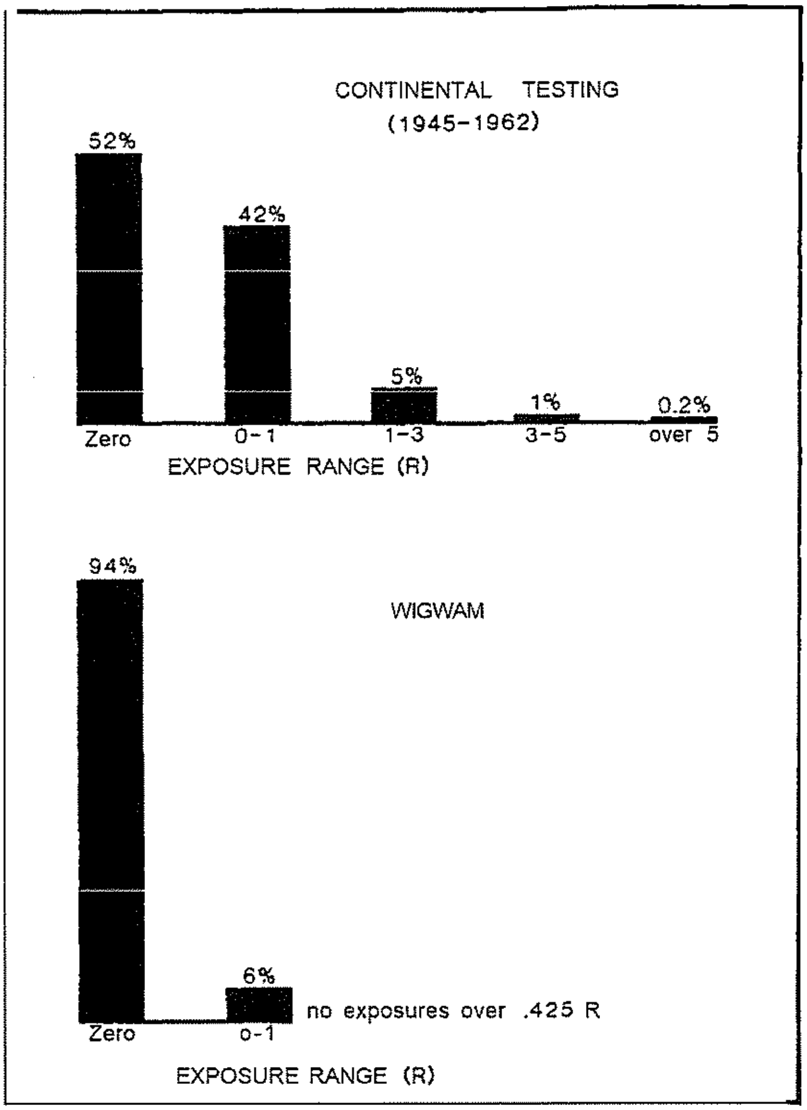

Figure 4-2. Exposure distribution, Continental Testing, (1945-1962) compared to WIGWAM.

These few statistical comparisons graphically illustrate that WIGWAM exposures were considerably below those experienced elsewhere in the testing program. The average exposure for the 362 WIGWAM individuals with non-zero exposures was 0.129 R, which is about the average annual exposure to naturally occurring background radiation in the United States.

The information presented in Figures 4-1 and 4-2 compares WIGWAM exposures with participant exposures at all oceanic testing sites (1946-1962) and all tests in the continental U.S. (1945-1962).

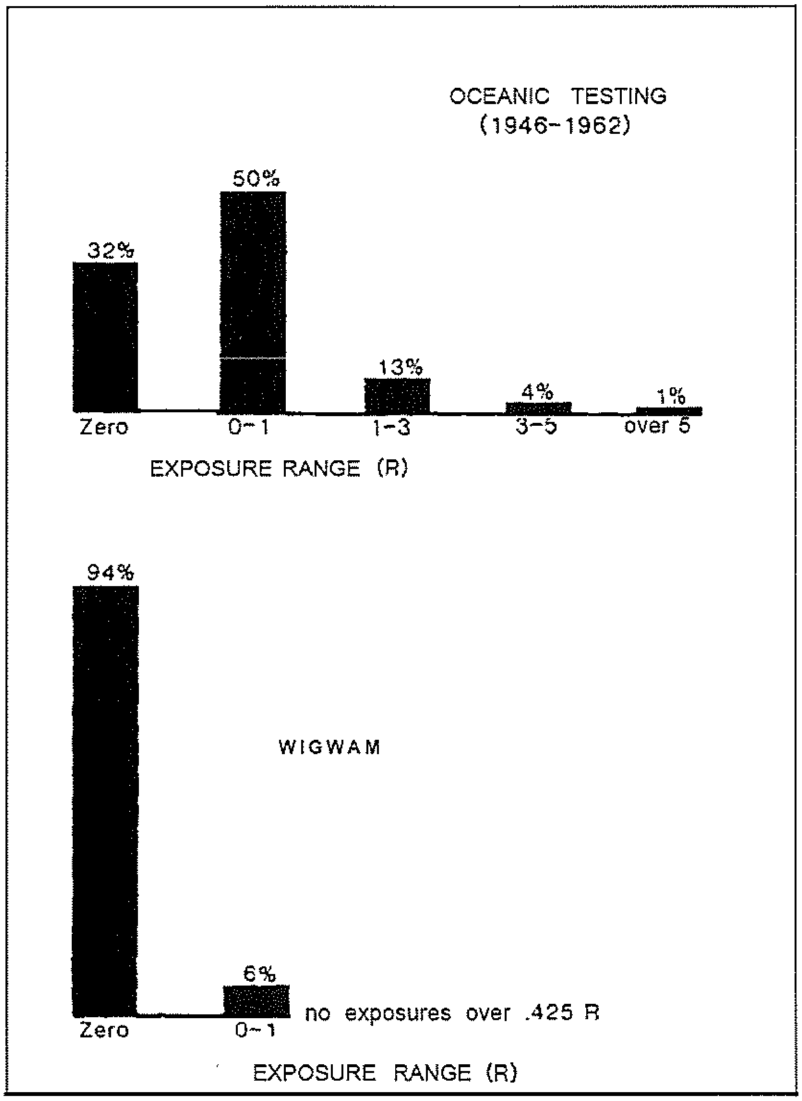

Figure 4-1. Exposure distribution, Oceanic Testing (1946-1962) compared to WIGWAM.

radiological survey fell upon M/V Horizon. Results of these activities are shown in Appendix D. Navy craft in the boat pool and the towing and salvage task element also entered radioactive water to recover experimentation and to salvage portions of the test array.

4-5 STATISTICAL DESCRIPTION OF RADIOLOGICAL EXPOSURES.

Research and records indicate that all WIGWAM participants were issued film badges and those whose activities might bring them into radiation exposure areas wore additional "daily" badges. Approximately 3.4 percent of the badge data were not recovered, principally because of damaged or lost film badges. Exposures less than 0.100R* were considered to be zero because the WIGWAM Rad-Safe Team used this as a detection threshold to allow for the uncertainties involved in measurements of exposure by photographic film under field conditions. Table 4-1 displays the exposure distribution of the combined WIGWAM participants and also participants on selected ships of interest: YAG-39, YAG-40, M/V Horizon, Boat Pool, ships from the towing and salvage task element, and the USS WRIGHT (Rad-Safe section). The Horizon listing includes operating personnel and SIO personnel participating in experimentation. Exposures for all personnel at WIGWAM are summarized by category in Appendix J.

TABLE 4-1 WIGWAM Exposures

				Exposure Category (R)			
	Number of Badges	Dosimetry Unavailable	Zero Exposure	.100-.165	.200-	.315-.395	425
All WIGWAM	6,732	229	6,141	329	19	13	1†
YAG-39	49		42	6	0	0	0
YAG-40	48	0	47		0	0	0
M/V Horizon/SIO	59	10	18	27	2	2	0
Boat Pool	230	18	181	30	1	0	0
USS CHANTICLEER(ARS-7)	96	0	15	80	1	0	0
USS TAWASA(ATF-92)	73	0	35	36	2	0	0
USS BOLSTER(ARS-38)	91	0	65	24	1	0	0
USS WRIGHT(CVL-49)	924	45	839	36	0	0	0

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* The data in this chapter are extracted from records of the Naval Radiological Defense Laboratory, NRDL (now a disestablished facility). These records are exposure data and therefore are expressed in roentgen (R). To express these data as dose, the radiation-unit relation discussed in Appendix C must be used.

† The highest exposure was received by a member of the aviation support provided by NAS, San Diego

4-4.2 Downwind Units.

Some few ships involved with experimental programs did have opportunity for small exposures subsequent to the detonation, either from downwind fallout or from contaminated seawater.

4-4.2.1 Ships Exposed to Downwind Fallout.

The ships located downwind, as shown in Figure 1-5, were the YAG-39 and YAG-40. These converted liberty ships were originally to be remotely controlled. However, at WIGWAM, well-shielded control rooms were provided for the crews. These ships were exposed to the airborne radiological environment as described in Appendix D, WIGWAM Radiological Environment. At H-hour the operating crews and project personnel were assembled on the flight deck. After the surface phenomena were observed, and before the arrival of the fallout, all personnel moved to the shielded control rooms. Automatic, remotely controlled decontamination systems reduced deck contamination to acceptable levels before selected personnel resumed duties on deck. A detailed description of YAG-39 and YAG-40 activities, including their tracks through the contaminated water areas, are found in Appendix D. Due to damage to its boiler system from the immediate shock wave, the YAG-39 remained outside the contaminated area from approximately H + 45 minutes until H + 5 3/4 hours. Because of the shielding afforded operating personnel in the Secondary Control Room and because of the Rad-Safe procedures employed, the dosage received by personnel on YAG-39 and YAG-40 during the entire operation was very low (Reference 6).

4-4.2.2 Ships Exposed to Contaminated Seawater.

In order to track and measure the pool of contaminated water, some ships were operated in the area during a 10-day period after detonation. It can be seen from the ships' tracks in Appendix D that YAG-39 traversed the contaminated area on both D-Day and D+1 while YAG-40 traversed the contaminated area from D-Day to D+3; however, the principal tracking vessels were from Scripps Institution of Oceanography: M/V Horizon, M/V Baird, and T-Boat. Baird was principally sampling organisms and T-Boat had only a limited capability. Therefore, the burden for the

CHAPTER 4

PERSONNEL EXPOSURES AT WIGWAM

4-1 INTRODUCTION.

The preceding chapters describe the participants, operations, and radiological safety activities at Operation WIGWAM. This chapter will, first of all, identify the principal units which had opportunity -- and those that did not have the opportunity -- for exposure to ionizing radiation. This chapter will also evaluate the extent to which these units were exposed.

4-2 BEFORE THE DETONATION.

Prior to the detonation of the nuclear device, no joint task force personnel were exposed to ionizing radiation. The area selected for the test was located away from previous test areas in the Pacific Ocean, and there was no opportunity for predetonation exposure. By contrast, testing at the Nevada Test Site, Enewetak and Bikini generally involved test preparation activity requiring some proximity to old and decayed contaminated areas.

4-3 AT DETONATION TIME.

At detonation time, all units were deployed as shown in Figure 1-5. The entire task force was heading north, into the wind. The closest ships were 5 miles from the point of detonation. Due to the depth of the detonation point and the short ranges of prompt neutrons and gamma rays in water (on the order of a meter or less) there was no prompt radiation exposure to personnel during WIGWAM.

4-4 AFTER THE DETONATION.

4-4.1 Upwind Units.

Most ships were upwind of the detonation and remained there during the post-detonation phase. These ships had no opportunity for exposure to ionizing radiation.

The system worked well in all functions. All users reported 100 percent reception of time signals.

No recovery operations were required in this program.

3-3.3 Program VI - Photographic Services for Operation WIGWAM (Reference 9)

This program provided photographic support for the Operation. Activities included filming subject matter of operational, documentary, historical, and technical or scientific interest. Films and scripts were prepared, as required, by the various groups which used the program.

3-3.4 Program VII - Radiological Support Element (References 2 and 3)

This program is described in the planning documents for WIGWAM as being the transit of the surface zero area shortly after shot time with suitably equipped, remotely controlled survey ships. These ships were intended to measure the contamination as to amount and extent at the earliest times. The plans for remote control of the ships were not used. Instead, the ships (the YAGs 39 and 40) were equipped with well-shielded control rooms for the crew. The operations of these manned YAGs are described in Appendix D. The requisite contamination data were obtained in these YAG operations.

3-3.5 Program VIII - Oceanographic Support Element (References 2 and 3)

Program VIII's purpose was to conduct oceanographic investigations prior to, during, and subsequent to Operation WIGWAM. In the planning phases of Operation WIGWAM, four possible sites were investigated prior to selection of the area about 500 miles southwest of San Diego. Aspects of this area which made it favorable for a deep underwater shot were mainly that ocean currents were such that contaminated water would travel thousands of miles before touching a shoreline, the fish population was too sparse to be commercially interesting, and shipping was sparse.

After the shot, surveillance of contaminated water and study of sea life continued. This work is reported as part of Program II (see Section 3-2.2).

Radiological Defense Laboratory (NRDL) investigated radiochemical and physical chemical properties of products of a deep underwater nuclear explosion, (Project 2.3), the potential radiological hazard to personnel (Project 2.4), and fallout and airborne activity (Project 2.7).

3-2.3 Program III - Target Response.

This program examined the effects of the shock wave on submerged targets and on instrument barges. The David Taylor Model Basin (DTMB) was responsible for the majority of target response projects. DTMB experiments were designed to study the lethal range of WIGWAM targets (Project 3.1), hull response and shock motion (Project 3.2, Parts 1 and 2), vibration characteristics of certain items on various targets and instrument barges (Project 3.3), the response of submerged targets (Project 3.4), and the depth, trim, heading, and flooding of WIGWAM targets (Project 3.6). An NRL project (Project 3.2.1) measured the shock motion of target barges. The Long Beach Naval Shipyard (LBNS) designed and built the WIGWAM targets (Project 3.8), and NEL supervised the modification and outfitting of instrument barges (Project 3.9).

3-3 SUPPORT PROJECTS.

3-3.1 Program IV - Weapon Characteristics.

Program IV consisted of 5 projects; 4.1 through 4.5. In summary, the objectives of Program IV were: to provide a bomb case and support suitable for the intended underwater use; to procure, assemble, and arm the required weapon; to make measurements of bomb yield by radiochemical and shock wave measurements; and, finally, to measure air pressures caused by the underwater explosion at the surface and at altitudes of a few thousand feet. A description of each project is included in Appendix I.

3-3.2 Program V - Timing and Firing (Reference 8)

Program V consisted of a single project which was to provide, install, and operate a timing and firing system for the weapon and for the various scientific experiments.

WIGWAM Technical Projects
(Continued)

Projects	Title	Sponsor	Section
Project 3.8	Design and Construction of WIGWAM Targets	LBNS	3-2.3
Project 3.9	Modification and Outfitting of Instrument Barges	NEL	3-2.3

WIGWAM Technical Projects
(Continued)

Program III: Target Response

Projects	Title	Sponsor	Section
Project 3.1	Lethal Range of WIGWAM Targets Based on Hull Response and Applied Pressure Measurements	DTMB	3-2.3
Project 3.2 (Part 1)	Hull Response and Shock Motion--Background, Instrumentation, and Test Results	DTMB	3-2.3
Project 3.2 (Part 2)	Hull Response and Shock Motion--Discussion and Analysis	DTMB	3-2.3
Project 3.2.1	Shock Motion of YFNB Targets	NRL	3-2.3
Project 3.3	Vibration Characteristics of Certain Items on SQUAW-29, YFNB-29, and PAPOOSE C	DTMB	3-2.3
Project 3.4	Response of SQUAW Targets from High-Speed Motion Pictures of Interior	DTMB	3-2.3
Project 3.6	Depth, Trim, Heading, and Flooding of WIGWAM Targets	DTMB	3-2.3

WIGWAM Technical Projects
(Continued)

Projects	Title	Sponsor	Section
Project 2.6 (Part 2)	Mechanism and Extent of the Dispersion of Fission Products by Oceanographic Processes, and Locating and Measuring Surface and Underwater Contamination	SIO	3-2.2
Project 2.6 (Part 3)	Radiological Techniques and Instruments Used for the Oceanographic Survey on Operation WIGWAM	SIO	3-2.2
Project 2.7	Fallout and Airborne Activity in Operation WIGWAM, with Notes on Surface Effects	NRDL	3-2.2
Project 2.8 (Part 1)	Subsurface Configuration of the Array	SIO	3-2.2
Project 2.8 (Part 2)	Physical Oceanography of the Test Area	SIO	3-2.2
Project 2.9	Measurement of Secondary Effects: Water Waves	SIO	3-2.2

WIGWAM Technical Projects
(Continued)

Program II: Radiological and Oceanographic

Projects	Title	Sponsor	Section
Project 2.1	Collection of Early Water Samples for Radiochemical Analysis and Yield Determination	SIO	3-2.2
Project 2.2	Radiochemical Analysis of WIGWAM Debris	NRL	3-2.2
Project 2.3	Radiochemical and Physical Chemical Properties of Products of a Deep Underwater Nuclear Detonation	NRDL	3-2.2
Project 2.4	Determination of Radiological Hazard to Personnel	NRDL	3-2.2
Project 2.5	Effects of Nuclear Explosion on Marine Biology	SIO	3-2.2
Project 2.6 (Part 1)	Mechanism and Extent of the Early Dispersion of Radioactive Products in Water	SIO	3-2.2

Table 3-1. Operation WIGWAM Technical Projects.

Program I: Free-Field Measurements

Projects	Title	Sponsor	Section
Project 1.1	Predictions of Underwater Explosion Phenomena	NOL	3-2.1
Project 1.2	Underwater Free-Field Pressures to Just Beyond Target Locations	NOL	3-2.1
Project 1.2.1	Free-Field Pressures, Station Zero	NRL	3-2.1
Project 1.3	Underwater Free-Field Pressure Measurements	NEL	3-2.1
Project 1.4	Bubble Phenomena	NOL	3-2.1
Project 1.5	Photographic Measurements of Surface Phenomena	NOL	3-2.1
Project 1.6	Underwater Optical Measurements	ONR	3-2.1

DoD programs were closely related through the overall DoD objective of improving nuclear warfare capabilities. Table 3-1 lists the Operation WIGWAM Technical Projects and the section of Chapter 3 in which the project is described. More detailed summaries of them are provided in Appendix I. The Support Projects are briefly described in Section 3-3.

3-2.1 Program I - Free-Field Measurements.

The free-field measurement program investigated water shock wave and surface pressure phenomena associated with a deep-water nuclear burst. The program included projects conducted by the U.S. Naval Ordnance Laboratory (NOL) examining underwater explosion phenomena (Project 1.1), underwater free-field pressures in the immediate target area (Project 1.2), phenomena associated with the explosion bubble (Project 1.4), and photographic measurements of surface phenomena (Project 1.5). The Naval Research Laboratory (NRL), the Navy Electronics Laboratory (NEL), and the Office of Naval Research (ONR) investigated free-field pressures at station zero (Project 1.2.1), underwater free-field pressures (Project 1.3), and underwater optical phenomena (Project 1.6), respectively.

3-2.2 Program II - Radiological and Oceanographic.

Program II studied the radioactive products of the nuclear burst, the distribution and movement of such products in water and air, and determined the hazards to personnel aboard vessels traversing the contaminated area. The Scripps Institution of Oceanography (SIO) made radiochemical analyses and yield determinations of early water samples (Project 2.1), studied the effects of the nuclear detonation on marine life (Project 2.5), the mechanism and extent of the dispersion of radioactive products in water (Project 2.6, Parts 1 and 2), the radiological techniques and instruments used for the WIGWAM oceanographic survey (Project 2.6, Part 3), the subsurface configuration of the array (Project 2.8, Part 1), the physical oceanography of the test area (Project 2.8, Part 2), and water wave secondary effects (Project 2.9). The Naval Research Laboratory conducted a radiochemical analysis of WIGWAM debris (Project 2.2). The U.S. Naval

CHAPTER 3

OPERATIONS

3-1 INTRODUCTION.

As was pointed out in Chapter 1, Task Unit 7.3.1 was responsible for the scientific and support programs of Operation WIGWAM. Programs I-III were the technical projects. Programs IV-VIII were the support projects necessary to Programs I-III. The primary objectives of Programs I, II and III were:

- To determine the fatal range of a deeply detonated nuclear weapon for a typical, well-designed, modern submarine
- To determine the pressure-time field in water and in air resulting from such an explosion
- To determine the safe range for a surface ship in the vicinity of this detonation
- To determine the fallout and contamination problems resulting from the explosion.
- To determine the characteristics of any additional phenomena.

This chapter presents a detailed scenario of personnel activities, project by project, for eventual use in identifying the activities of those DoD personnel who may have been exposed to radiation. To this end, participation by scientific personnel is described for each DOD-sponsored project. Where details of personnel participation are limited, it is because the references are largely technical reports which, by their nature, do not describe such details.

3-2 TECHNICAL PROJECTS.

The Chief of the Armed Forces Special Weapons Project planned an integrated program of military effects tests, based on continuing study of the needs of the Armed Forces for data on the effects of nuclear weapons. All these

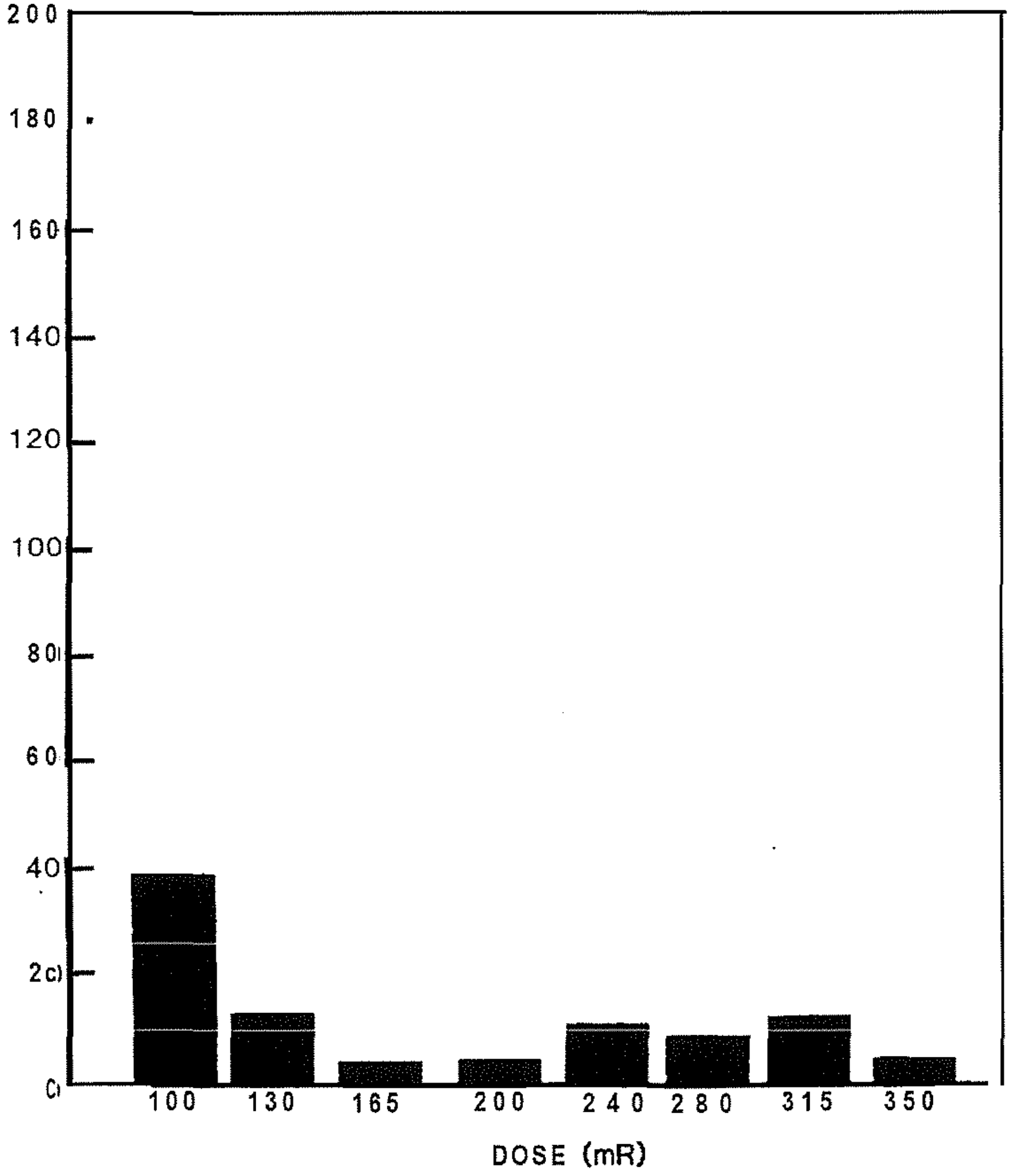

Figure 2-4. Distribution of daily film badge doses, WIGWAM.

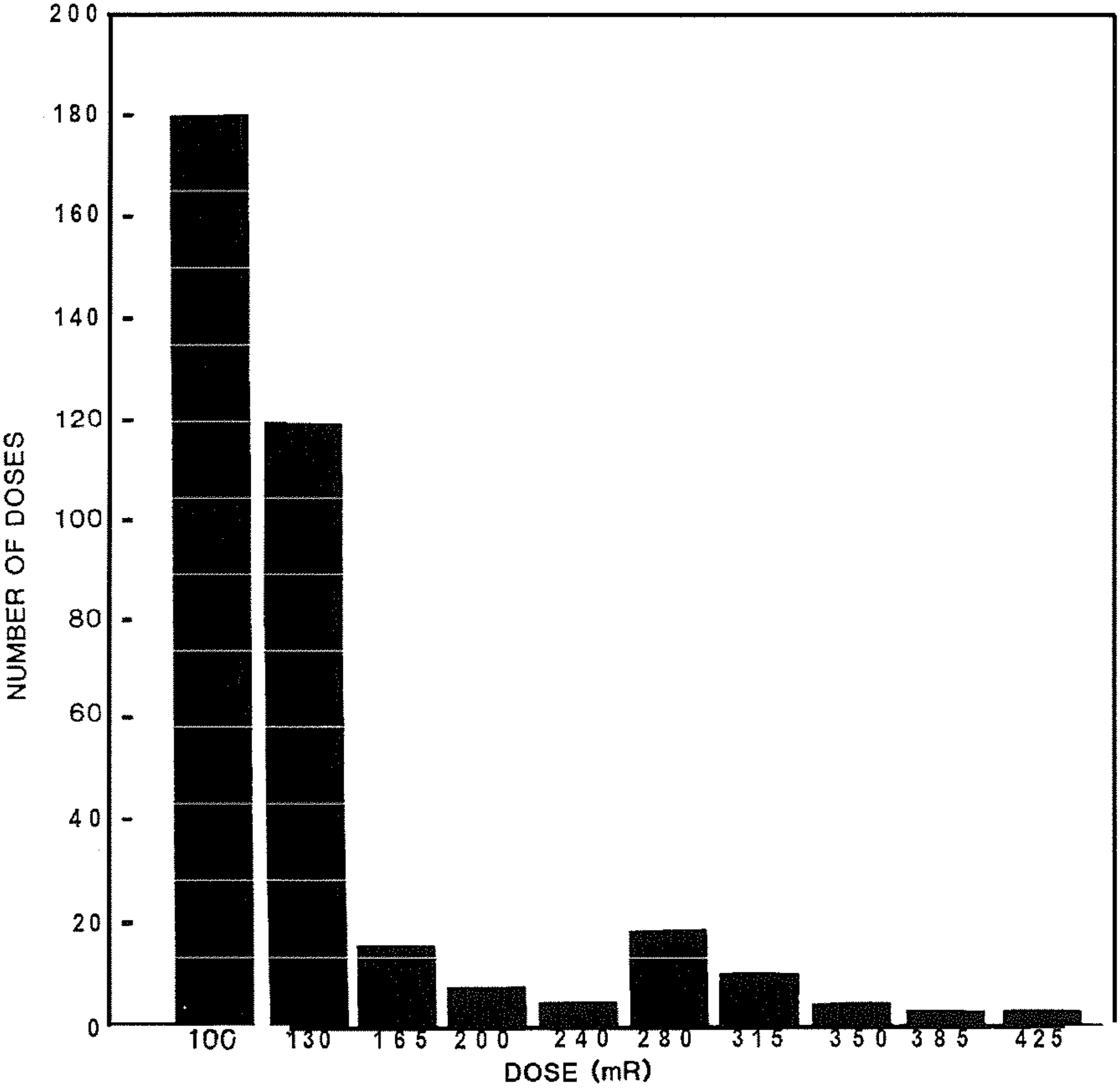

Figure 2-3. Distribution of operational film badge doses, WIGWAM.

The results of their analyses are described in the following quotation from Reference 4.

> "The dosages received were much lower than had been anticipated due to the low levels of contamination which occurred during the Operation.
>
> Operational badge results indicated 350 positive gamma exposures (100 mr or greater), average 132 mr and with a maximum of 425 mr [Figure 2-3 shows the distribution of operational badge dosages]. Film-data were read to the nearest scale unit on a densitometer and were then converted to dosage values.*
>
> Daily badge results indicated 74 positive gamma exposures (100 mr [gamma] or greater), averaging 159 mr and with a maximum of 350 mr. [The distribution of daily badge dosages is plotted in Figure 2-4.]
>
> A total of 318 personnel wore one or more daily film badges in addition to their operational film badges. A large portion of these daily badges showed zero indicated exposure, whereas 288 individuals who did not wear daily badges received dosages on their operational badges.
>
> No detailed study was made of beta exposures. The maximum individual beta exposure indicated was of the order of 1,600 mrep. Badge-indicated beta-to-gamma ratios range from 1:1 to 3:1. The low contamination experienced during the operation precluded extensive beta exposures."

References 1 and 4 state that Project 0.17 was eminently successful in carrying out its mission for Operation WIGWAM. Of the badges issued, only 362 received positive gamma exposures (100 mR or greater) and of those, the maximum exposure was 425 mR, equal to about one-ninth of the 3.9 R safe limit.

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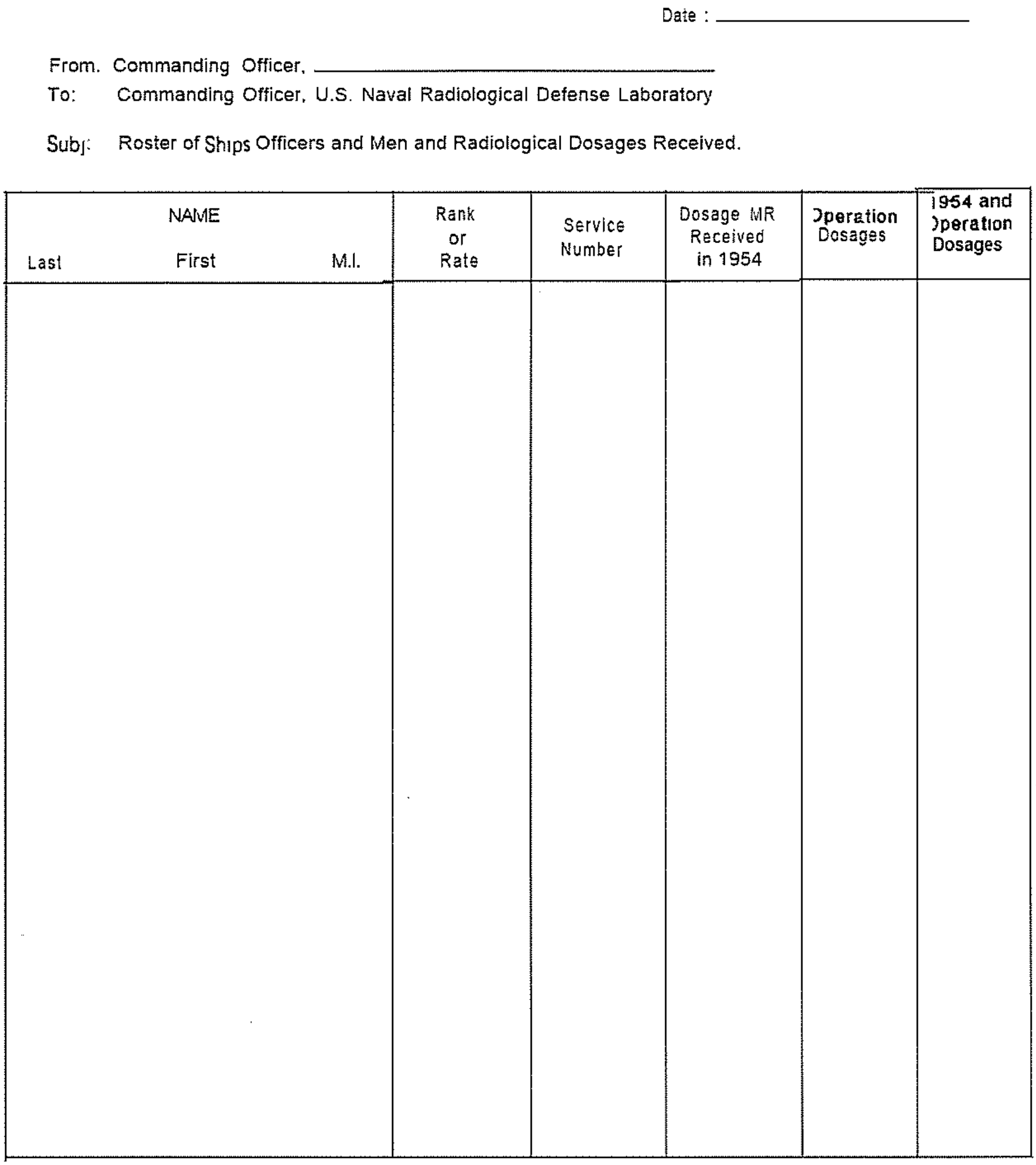
*This procedure provided a capability to measure dose with a resolution of ± 40 mr, and a threshold of 100 mr.



Date : ____________________

From. Commanding Officer, ______________________________

To: Commanding Officer, U.S. Naval Radiological Defense Laboratory

Subj: Roster of Ships Officers and Men and Radiological Dosages Received.

NAME			Rank or Rate	Service Number	Dosage MR Received in 1954	Operation Dosages	1954 and Operation Dosages
Last	First	M.I.					

Figure 2-2. Form used to record WIGWAM and previous radiological dosage record of personnel.

Rad-Safe personnel were withdrawn from the ship at H + 55 hr."

2-4.4 Dose Control and Measurement by Film Badge.

A two-badge photodosimetry system was used during Operation WIGWAM. One badge, known as the operational badge, served as the legally required record for exposure during the entire period of personnel participation in Operation WIGWAM. One operational badge was issued to each member of Task Group 7.3. The other badge, the daily badge, was used for dosage control purposes and was issued each day to all members of the Task Group who were engaged in sample or equipment recovery work, or who were otherwise likely to receive any radiation exposure. Readings of daily badges from the previous day were available so that a decision could be reached on whether or not an individual could receive any further exposure.

Rosters of all personnel participating in Operation WIGWAM were prepared on special forms (Figure 2-2). These forms were used to record the exposures received during Operation WIGWAM, and also carried information as to the radiation dose an individual received during the previous calendar year, 1954. The Rad-Safe section aboard the USS WRIGHT (CVL-49) supported and coordinated the dosimetry program. Copies of these forms, containing the exposures of WIGWAM participants, have been located by the Navy NTPR team.

The film used was Dupont film packet 559, which consisted of two dosimetric films: emulsion No. 502 and emulsion No. 606, which provide overlapping dose responses ensuring coverage between 0.1 and 600 R.

Operational badges were issued through the administration of each Task Group ship unit on day D-2. Daily badges were issued to those personnel involved in post-shot operations.

2-5 OVERALL RESULTS OF WIGWAM RAD-SAFE PROGRAM.

After completing Operation WIGWAM, Task Group 0.17 analyzed the personnel exposure records from the two sets of badges, operational and daily.

"The survey disclosed a general background in the engine room of 15 mr/hr as a result of contamination of the hull and engine cooling-water space. The engine cooling water discharge line was contaminated to 120 mr/hr at contact, and the main deck and topside spaces were contaminated from 2,500 to 25,000 c/m* as a result of the ship's work in a contaminated water area.

A briefing on the activity levels present, clearance levels desired, and decontamination methods was given to the ships' crew by the Project 0.17 representative.

Ship decontamination procedures were initiated by the ship's crew, with the advice of Rad-Safe personnel, starting with a salt-water washdown which resulted in a 60 percent reduction in activity levels. Hand scrubbing with fresh water and detergent was quite effective in reducing the remaining deck and horizontal surface contamination to levels less than 100 c/m. Hose, canvas, and wood surfaces which remained contaminated to levels of 1,000 to 20,000 c/m were segregated for further natural decay to safe levels.

An activity level of 4,000 c/m average in the interior spaces was decontaminated to less than 1,000 c/m by means of fresh water and detergent.

By H + 31 hr the general background in the engine room had dropped to 4 mr/hr, and the cooling-water discharge line had dropped to 60 mr/hr at near contact.

During the decontamination operations, a station for the decontamination of personnel was set up in the crew's head. All decontamination crews were processed through this station. All personnel decontamination measures were effective except for three stubborn cases of hand contamination, maximum level remaining, 1,200 c/m.†

The ship's captain was advised of the radiological status of the ship, operating precautions were recommended, and

---

*c/m = counts per minute, normally abbreviated CPM. The relationship between CPM and mR/h depends upon the type of radiation and the energy of the radioactive particle or photon.

†As noted in Appendix F, the maximum permissible activity on the skin was 1,000 CPM. The hand contamination was slightly higher and allowed to decay naturally.

On D-day and on subsequent days, aerial surveys showed the general location and size of the contaminated water area and the radiation levels. These surveys gave the recovery parties a general idea of the location of the contaminated water.

The depth of detonation resulted in very little airborne contamination and, with the prevailing wind blowing away from the task force, only a few experimental ships were exposed. Continuous and spot air sampling was done from H-hour to H + 10 to monitor for possible fallout. No traces of fallout were detected at the air sampling stations aboard the various Task Group support units.

2-4.3 Personnel Movement Control.

Since contamination areas could not be marked except on board ships, Rad-Safe monitors accompanied work parties and continuously monitored their activities. This activity is illustrated in a quotation from Reference 4 concerning the Rad-Safe operations on a vessel, the USS CHANTICLEER (ASR-7). In the quotation, the YFNB units mentioned were covered lighters used in the target array. One of these, YFNB-13, was positioned at approximately 7,800 feet up the towline from surface zero, supporting the submerged test vessel, the SQUAW-13, which simulated a submarine hull.

> "Both continuous and spot air sampling was done from H-hour to H + 10 hr to monitor for possible fallout. No traces of fallout were detected at the air-sampling stations aboard the various Task Group support units.
>
> Following the initial helicopter survey which reported negative readings on all YFNB units of the array, at H + 1 hr the ASR-7 approached the YFNB-13 and placed a working party aboard. A Rad-Safe survey confirmed the negative readings obtained on the helicopter survey. The ASR-7 encountered an area of contaminated water at about H + 16 hr, when readings of 95 mrep/hr, including 75 mr/hr* of gamma radiation (20 mrep/hr beta plus 75 mrep/hr gamma), were obtained at a distance of 6 ft from the water surface. At H t 23 hr the ship returned to a clean area, and a complete ship monitoring survey was made.

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*The Defense Nuclear Agency now abbreviates mr/hr as mR/h (See "Standards for DNA Scientific and Technical Reports").

material summarized below is the report "Radiological Safety for Operation WIGWAM", Reference 4.

2-4.1 Rad-Safe Education and Training.

In preparation for Operation WIGWAM, Rad-Safe personnel were trained and indoctrinated. Three courses of instruction were given to selected groups of personnel as follows:

- Course I - A 4-week course for training of civilian shipyard personnel as Rad-Safe monitors
- Course II - A 3 1/2-day course for indoctrination of scientific personnel in Rad-Safe principles.
- Course III - A 5-day course to indoctrinate personnel from Navy support ships in Rad-Safe principles.

Descriptions of the material covered in these courses, taken from Reference 4, are given in Appendix H.

In addition to this training, a 182-page training manual,* "Radiation and Contamination Control," was prepared and distributed to personnel.

2-4.2 Contamination Control.

The nature of the recovery operations was such that it was not feasible to establish radiation exclusion areas by a prior general monitoring of the area. A zone system of contamination control was used in cases where practicable. Where a portion of a deck area of a ship was contaminated, boundaries were set up surrounding the location and controls established over personnel and equipment entering and leaving the area. General contamination control measures included tagging or marking with hazard warning signs, on-the-spot decontamination, or immediate disposal of contaminated materials.

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* This manual has not yet been located.

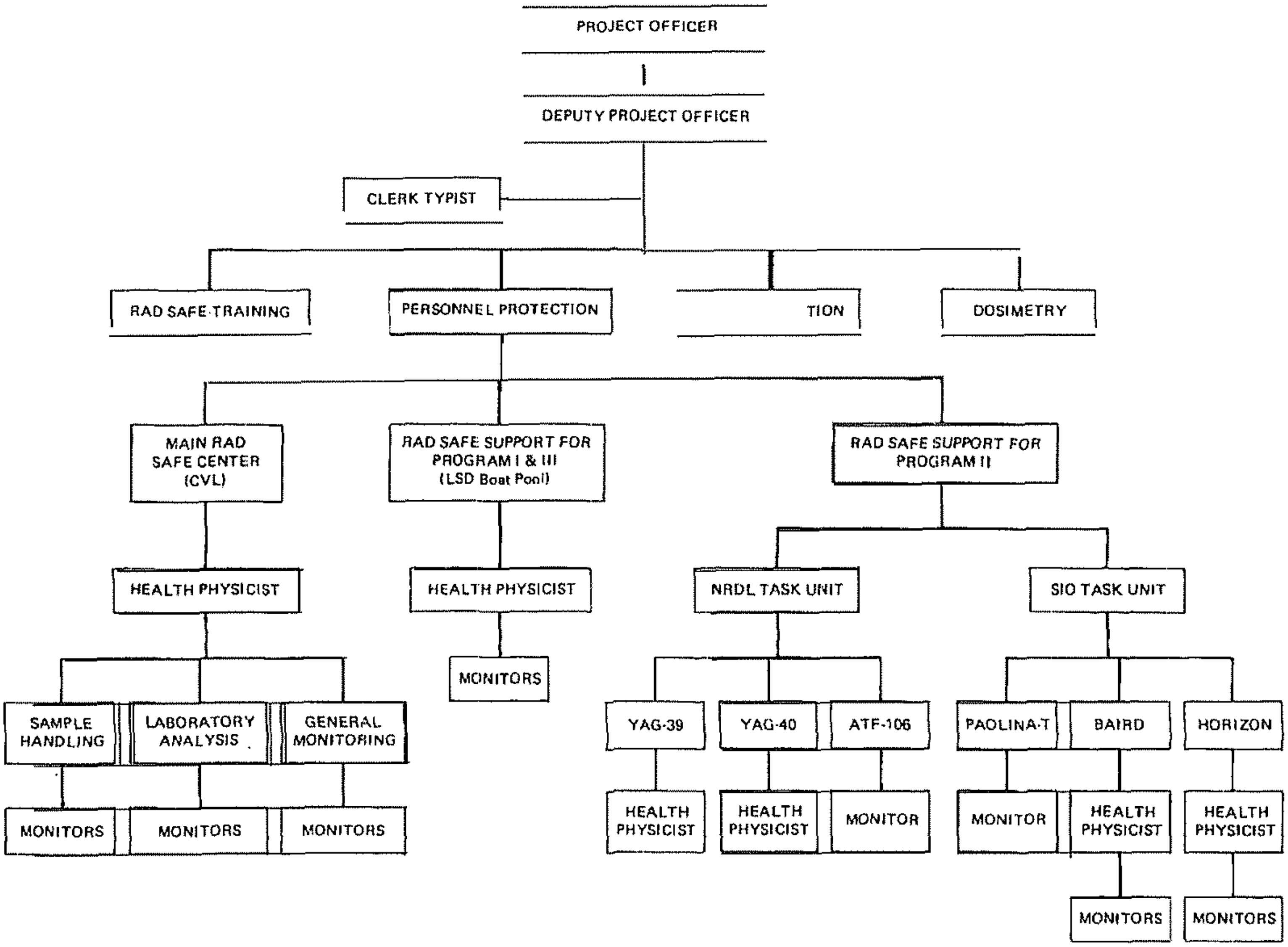


Figure 2- . Organization on D-day, Project 0.17,
Rad-Safe for Operation WIGWAM.

The Task Group Commander assigned basic responsibility for Project 0.17 to the U.S. Naval Radiological Defense Laboratory (NRDL), whose Health Physics Division conducted the project. Since personnel requirements for the project far exceeded those available at NRDL, military and civilian support was requested and obtained from the Armed Services and from the AEC.*

> A Rad-Safe section was established aboard the USS WRIGHT (CVL-49) to support the operation. Various substations were set up on other ships to provide direct support for the scientific equipment.

The organization of Project 0.17 personnel is shown in Figure 2-1. There were four main groups:

- Rad-Safe training
- Personnel protection
- Instrumentation
- Dosimetry.

The Personnel Protection Group was further subdivided into three units that performed Rad-Safe services for several operating units of the Task Group:

- The main Rad-Safe Center for general support
- Rad-Safe services for Programs I and III
- Rad-Safe for Program II.

2-4 RAD-SAFE PROCEDURES AND OPERATIONS.

This section outlines how the essential on-site Rad-Safe functions were conducted: personnel education, identification of contamination sources, control of personnel movements, and exposure control by film badge. The source for the

---

*A roster of the personnel in Project 0.17, taken from Reference 4, is contained in the separate list of participants.

of 100 below the AEC allowable concentrations. The small amount of airborne radioactive material associated with WIGWAM, and prevailing wind directions away from San Diego, make it questionable that this increase was due to WIGWAM.

2-2 RADIATION SAFETY STANDARDS.

The safety criteria for WIGWAM were set by Task Group 7.3 following guidance from the AEC. These criteria are reproduced in full in Appendix F. The basic limit for radiation exposure was that whole body dose was not to exceed 3.9 roentgen (R) for the duration of the operation. This was based on the then-accepted (1949-1956) value of 15R per year or 0.3R per week. (It was assumed that WIGWAM participants could receive the dose corresponding to one quarter year, i.e., 13 weeks.) Associated with this overall dose were specific Maximum Permissible Limits (MPLs) for the parts of the body, clothing and personal effects, food, water, air, equipment, and materials. Given this list of MPLs, the Rad-Safe function can be most simply described as monitoring the environment and each person for the quantities specified by the various MPLs and using the readings to control personnel activities so as to not exceed the standards.

2-3 ORGANIZATION.

The Commander, Task Group 7.3, was responsible for Radiological Safety, which was administered through command channels. The Rad-Safe organization, designated as Project 0.17, was set up to protect personnel from whatever actual radiological hazards might occur. The mission for this project was defined as the following:

- Effective training of personnel
- Protection of personnel and equipment
- Evaluation of the effectiveness of Rad-Safe training and radiac equipment*.

---

*See Appendix G where Annex G of the Operation Plan, Commander, Task Group 7.3, No. 1-55, is reproduced in full. Annex G described the Rad-Safe Plan.

2-1.1 Rad-Safe On-Site Plans.

The general plan for Rad-Safe operations consisted of four main elements. First, an education and training program was implemented to inform all participants of potential radiological hazards and of the means available to avoid them. Second, all sources of contamination were to be identified and clearly marked so that they would be easily recognizable. Access to them was to be controlled by physical means such as exclusion zones on ships, monitors, etc. As part of this latter activity, routine surveys of ships were to be made to ensure that the participants could identify all inadvertent sources of contamination. Third, all personnel movements in recovery operations were to be monitored and controlled as to their proximity to, and time spent in, contaminated water areas. Radiological instrumentation for ships expected to enter contaminated areas is shown in Appendix E. Fourth, the dose received by each participant was controlled and measured by a two-badge photodosimetry system. The details of how all these tasks were organized and performed, as well as the reported overall results of the Rad-Safe programs, are the concerns of this chapter.

2-1.2 Rad-Safe Off-Site Plans.

In addition to the Rad-Safe program for the participants in Operation WIGWAM, a Rad-Safe program was implemented for off-site areas. This off-site program consisted first of selecting a suitable site in the ocean. The site selected ensured that due to the pattern of the water currents, waters which might be contaminated had to travel thousands of miles before reaching a shoreline, and that the fish population was too sparse to be commercially interesting. Oceanographic and sea-life surveys after the shot showed that contamination levels in the water became insignificant in a few days. No effects were found on sea life. Monitoring of fish canneries found no evidence of fish contaminated by WIGWAM. Inasmuch as the responsibility for area monitoring fell within the scope of Project 0.17, preparations were made to measure fallout activities in the coastal areas of California. Existing fallout measurement stations were used in San Francisco and Los Angeles. A fallout monitoring station was established in San Diego and operated from 1 May to 15 June 1955. During 18-25 May, positive readings were obtained at the San Diego site. However, these were still a factor

CHAPTER 2

RADIOLOGICAL SAFETY AT OPERATION WIGWAM.

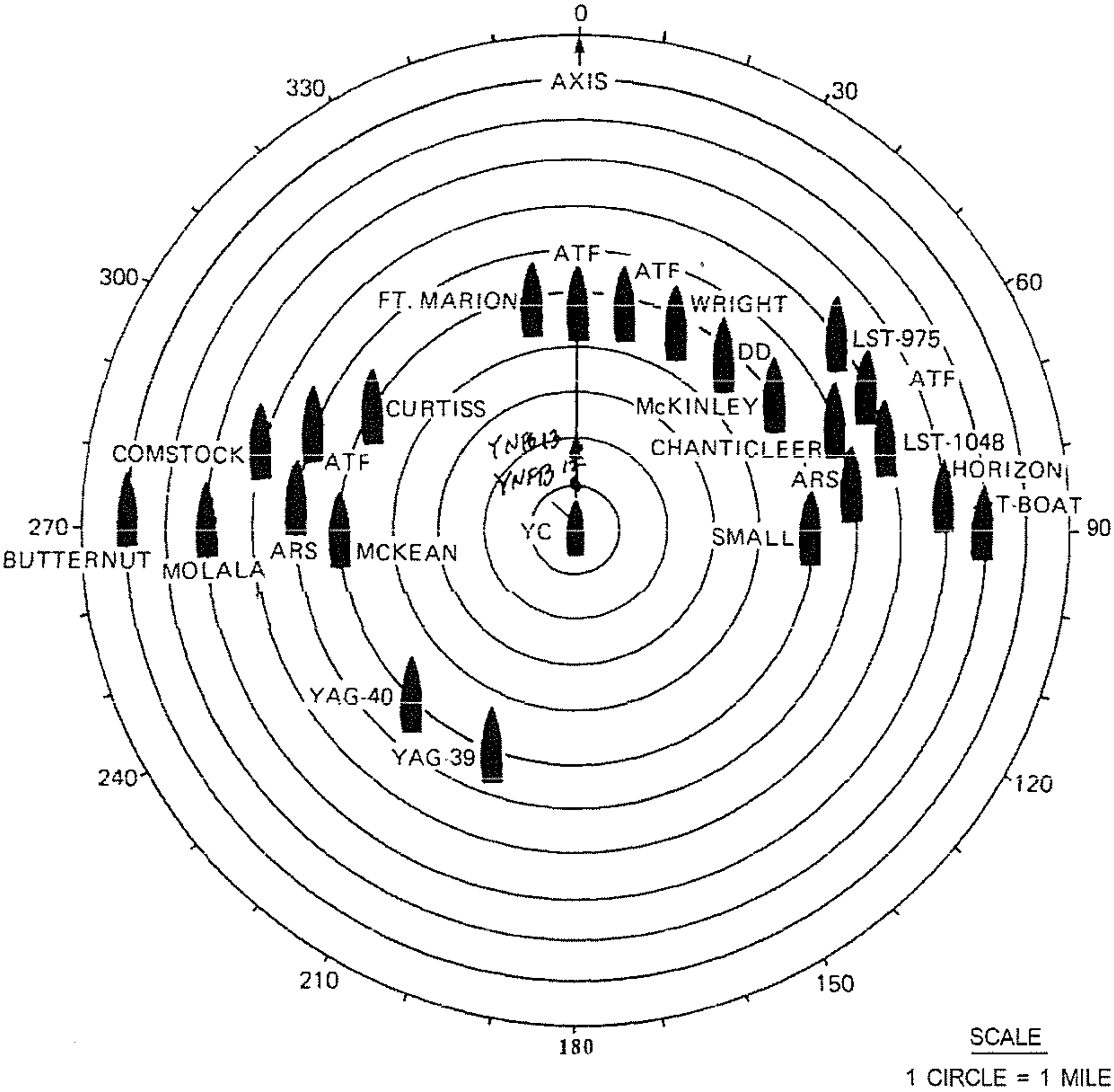
2-1 INTRODUCTION.

This chapter describes the Radiological Safety (Rad-Safe) operations carried out at WIGWAM. For a complete understanding of this chapter, the reader should be familiar with the concepts involved in protecting personnel from the hazards of ionizing radiation. For readers not thus familiar, Appendix C provides brief descriptions of the relevant concepts in nuclear radiation, radiological exposure and dose, radiological safety guides, etc.

This chapter describes the Rad-Safe programs for Operation WIGWAM as a whole. Details of personnel activities for specific projects that might have led to exposure are given in Chapter 3, if such details are available in the reference materials.

Shot WIGWAM was the first deep underwater nuclear burst; therefore, the post-shot radiological environment was not fully known in advance. It was known that the prompt nuclear radiation would not constitute a hazard to personnel, since the radiation would be completely absorbed in the seawater far below the surface. However, the gas bubble formed by the burst was expected to reach the surface in several seconds, and it would spread entrained weapon debris and other radioactive material on surface waters and in the atmosphere. As a result, the contaminated surface waters and fallout could pose potential hazards to personnel conducting post-shot operations in the vicinity of surface zero. Chapter 3 describes one of the main research programs in Operation WIGWAM, Program II, which was devoted exclusively to this subject: the study of local contamination and fallout accompanying a deep water burst, and their significance to naval operations. These studies and their results are further described in Appendix D, "WIGWAM Radiological Environment." Most of the material that follows on WIGWAM Rad-Safe is taken from Reference 4.

ATF = FLEET OCEAN TUG
LST = LANDING SHIP, TANK
ARS = SALVAGE CRAFT, TENDER
YAG = UTILITY SHIP (CONVERTED LIBERTY SHIP)
YC = UTILITY OPEN LIGHTER (TOWED)

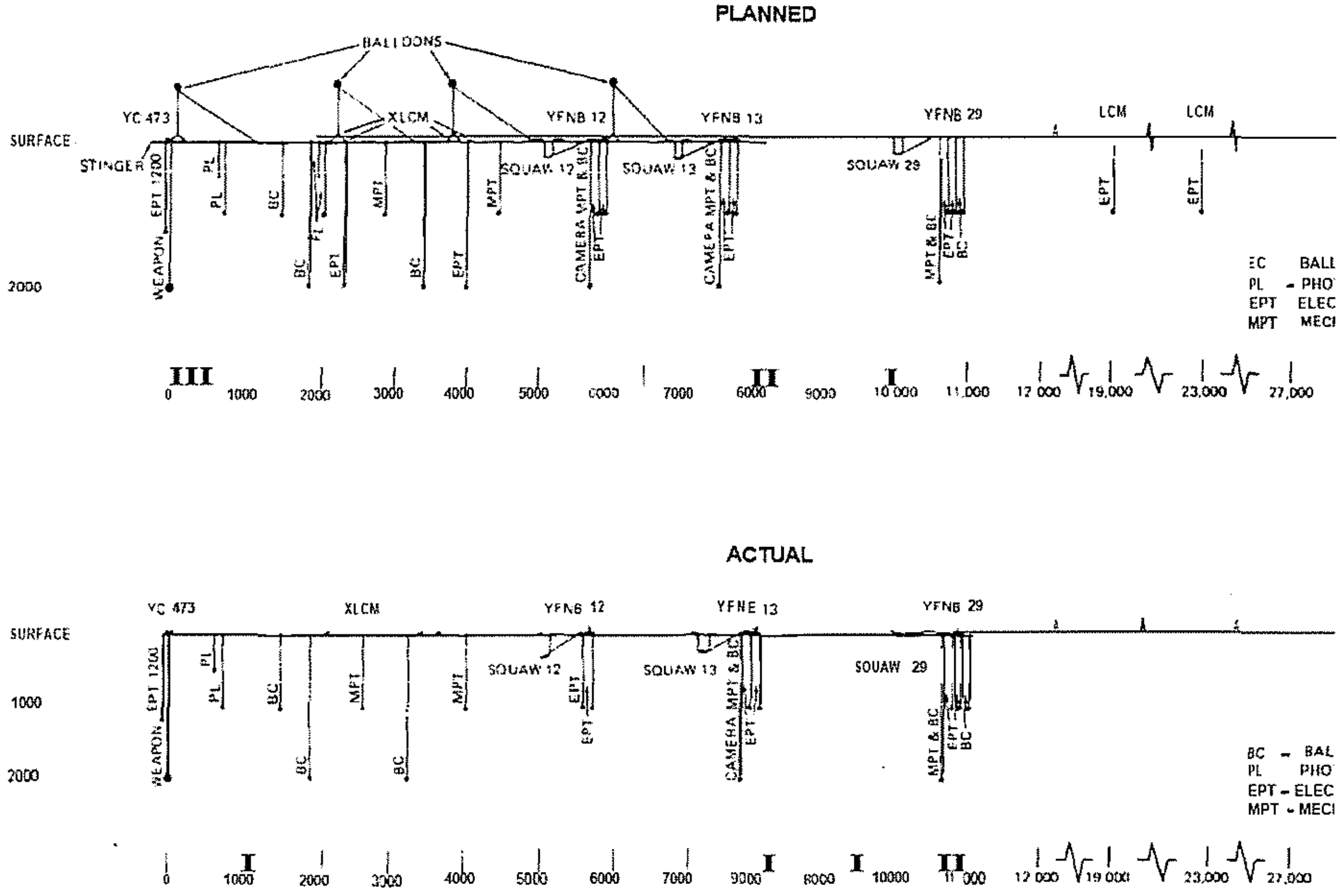


mile radius or diameter?

Figure 1-5. Ship stations at H-hour, Operation WIGWAM.

around it in the pattern shown in Figure 1-5. No vessel was closer than 30,000 feet (5 nautical miles) to the zero barge. The tow tug served as a reference for positioning of all ships. Stationkeeping tolerances were ± 2° in bearing and ± 200 yards in range.

Finally, all personnel were accounted for and were on ships clear of the test array. The ships were on station, as shown in Figure 1-5. A few seconds before 1300 hours, Pacific Daylight Time, on 14 May 1955, with this entire configuration of ships and the test array holding north into the wind, the first deep-water nuclear weapons test in history was detonated.



Note: All distance units are in feet.

Figure 1-4. Planned and actual target array, Operation WIGWAM.

1-6 SETTING.

The exact location of the shot was chosen after careful surveys and deliberation. At DoD request, Scripps Institution of Oceanography conducted a thorough survey of various locations in the Pacific, the Caribbean, and the Atlantic. The site had to be deep enough to contain the detonation, yet away from undersea or sea bottom perturbations such as sea mounts, ridges, islands, etc. Migratory fishing areas were to be avoided. The site selected was to have fairly well-known currents and thermal gradients, a predominance of good weather, and isolation from shipping lanes. The area selected, approximately 500 miles SW of San Diego, California, was judged to best fulfill the requirements. Figure 1-1 shows the location for the test.

The scenario for the actual test was as follows: A fleet ocean tug (ATF), on a fixed course, towed a 30,000 foot-long cable slowly on the surface at a speed such as to maintain the configuration of test objects suspended from the cable. Attached to the far end of the cable was the zero barge (YC-473, an open lighter) containing the nuclear device. This nuclear device was lowered to a 2000-foot depth several hours prior to detonation. At various points along the cable, a variety of instrument vessels, targets, instruments, and sampling stations were attached. Some were attached directly on the tow or device suspension cable, some were hanging in the sea on auxiliary lines attached to the tow cable, and some were suspended by balloons anchored to the tow cable. The submerged special submarine targets (SQUAWS) were supported by pontoons. The configuration of the test array as planned and as actually assembled for the test is shown in Figure 1-4. (The difference between the two arrays shows the effects of unfavorable weather and seas encountered during the passage to the test site and during the maneuvers that were required to assemble the 5-mile array.)

Assembly of the test array itself began on 12 May 1955, and was completed on the morning of 14 May. At this time, the Task Force vessels assumed the following configuration. The tug towing the test array moved into the wind slowly (0.5 knots) on a course due north (000°T). The zero barge followed, streaming out to the south at the end of a 30,000 foot cable. The Task Force vessels, moving on the same course as the zero barge, were arrayed

Table 1-1. WIGWAM participants.*

		Estimated No. of Participants
Office of Naval Research (Project 1.6)	ONR	17
Sandia Corporation (AEC Contractor)	SC (AEC)	23
Los Alamos Scientific Laboratory (AEC Contractor)	LASL (AEC)	1
University of California Research Laboratory (AEC Contractor)	UCRL (AEC)	3
Armour Research Foundation (AEC Contractor)	ARF (AEC)	8
Edgerton, Germeshausen and Grier (AEC Contractor)	EG&G (AEC)	13
David Taylor Model Basin	DTMB	11
Long Beach Naval Shipyard	LBNS	27
Lookout Mountain Laboratory	LML	14
Norfolk Naval Shipyard (Project 0.06)	NNS	1
U.S. Navy Electronics Laboratory	NEL	126
U.S. Navy Ordnance Laboratory	NOL	31
U.S. Naval Ordnance Test Station	NOTS	9
U.S. Naval Radiological Defense Laboratory	NRDL	54
U.S. Naval Research Laboratory	NRL	11
Scripps Institution of Oceanography	SIO	41
Woods Hole Oceanographic Institution (Project 0.13)	WHOI	3
Oak Ridge National Laboratory	ORNL	3
Official Visitors and Miscellaneous Observers		51
		447

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*Scientific Task Unit personnel only, does not include ships' crews (shown in Appendix B).

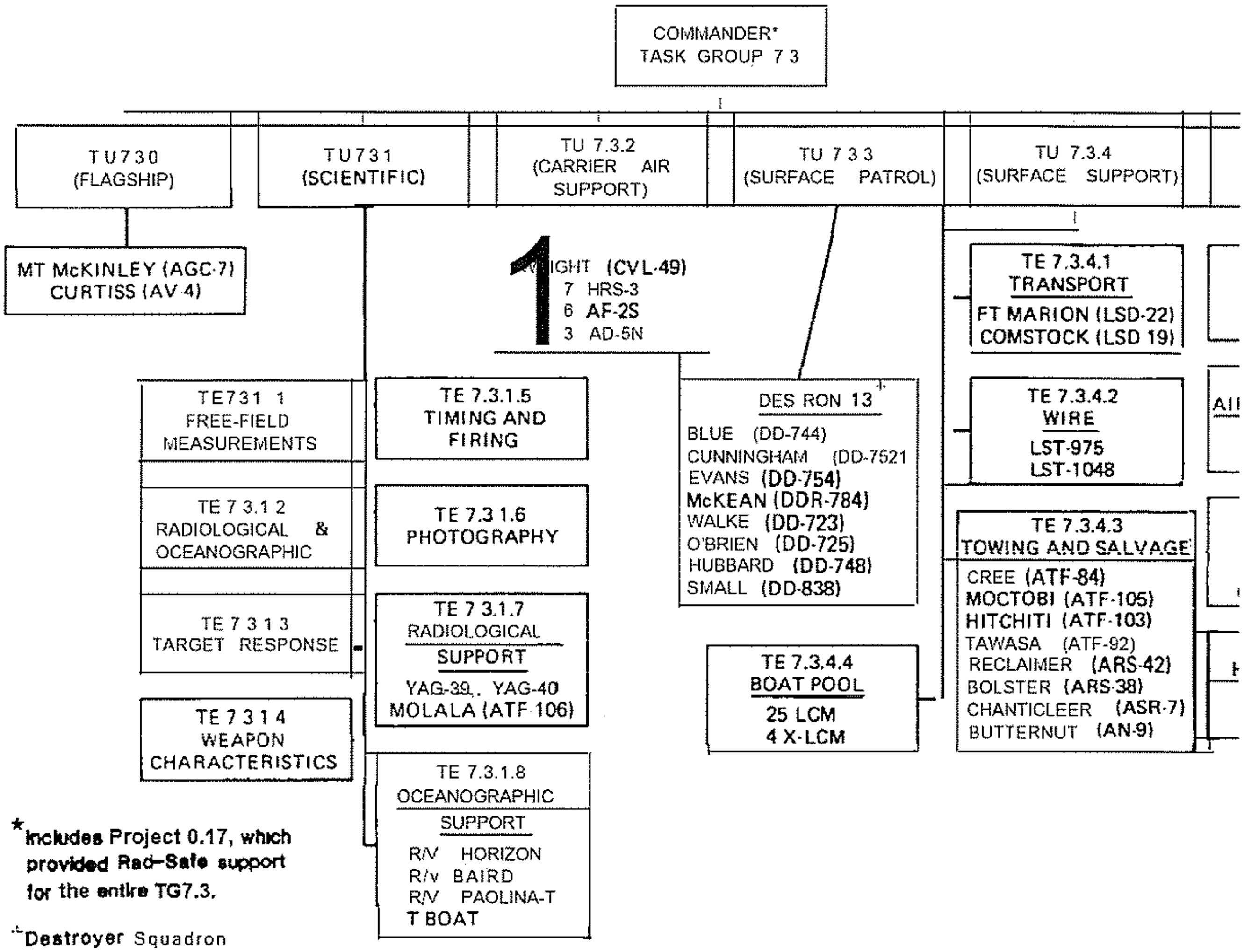
the ships (predominantly Navy) in each task element. These ships are further represented in Appendix B. All the ships shown in TE 7.3.1.8 were those of the Scripps Institution of Oceanography (SIO).

The Scientific Task Unit, TU 7.3.1, performed the weapon test activities during Operation WIGWAM. This TU not only fired the device, but also did the experimentation necessary to meet the objectives listed in Section 1-3 of this Chapter. The eight Task Elements shown under the Scientific Task Unit (Figure 1-3) represent eight separate programs which are described further in Chapter 3 and Appendix I (Reference 3):

- Program I, Free-Field Measurements
- Program II, Radiological and Oceanographic Measurements
- Program III, Target Response
- Program IV, Weapon Characteristics
- Program V, Timing and Firing
- Program VI, Photography
- Program VII, Radiological Support
- Program VIII, Oceanographic Support.

Although each Task Unit was principally staffed with Naval personnel, the Scientific Task Unit (TU 7.3.1) was comprised of many civilian employees from both military and civilian laboratories. These personnel were specialists in one or more of the many technical areas involved in the Operation. The participating laboratories are included in Table 1-1.

In addition to the Task Units shown in Figure 1-3, TG 7.3 had a Radiological Safety (Rad-Safe) Group, Project 0.17, which provided Rad-Safe support for TG 7.3 during Operation WIGWAM. This group, composed of 46 personnel (38 civilian, 8 USN military), is discussed further in Chapter 2 on Radiological Safety.



*Includes Project 0.17, which provided Rad-Safe support for the entire TG7.3.

⁺Destroyer Squadron

Figure 1-3. Organization of Task Group 7.3.

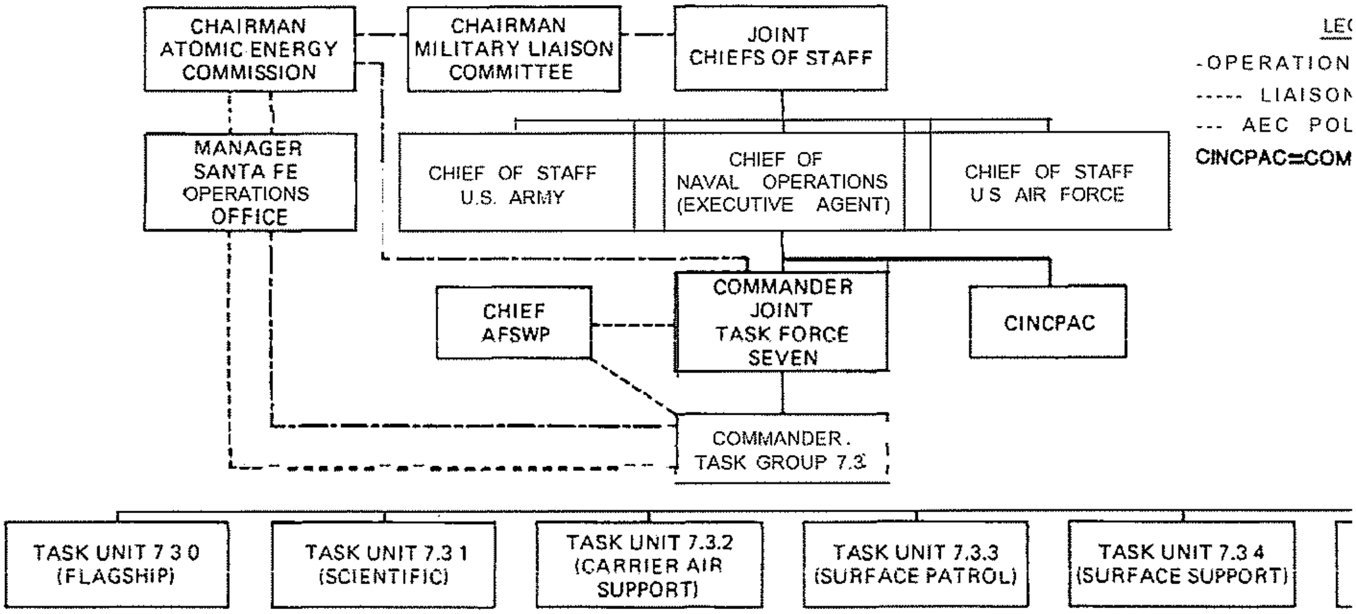


Figure 1-2. Joint Task Force Organization for Operation WIGWAM.

1-5 ORGANIZATION.

Operation WIGWAM was administered jointly by the AEC and the DoD. The organization for this particular event, however, differed from the organization of many former nuclear tests in that the DoD--and not the AEC--played the major role of command and execution. The AEC provided the nuclear device, the specialized personnel to fire the device, experimentation to measure outputs, and other services as required.

All nuclear testing in the Pacific was conducted by a joint task organization, Joint Task Force Seven (JTF7). Figure 1-2 depicts the command relationships for the Joint Task Force Organization as they existed for Operation WIGWAM. The DoD line of command extended from the Joint Chiefs of Staff and Service Chief, to the Commander, JTF7 (CJTF7). The Commander of the Navy element, Task Group 7.3 (CTG 7.3), was given authority to execute Operation WIGWAM within the guidelines established by the AEC.

The Commander in Chief, Pacific (CINCPAC), provided all movement, control, and logistics support, as well as general security of the WIGWAM test area for the Task Force. The Chief of the Armed Forces Special Weapons Project (AFSWP) was responsible for the technical direction of the weapons' effects tests, which were of primary concern to the Armed Forces at atomic tests.

The AEC had two major concerns at Operation WIGWAM: control possible radiation hazards to off-test-site populations, and to ensure the safety, security, and reliable detonation of the nuclear device.

The detailed plan for Operation WIGWAM (Reference 2) was published by Task Group 7.3 on 25 March 1955. This plan outlined the responsibilities and relationships for the DoD and the AEC, as shown in Figure 1-2.

The Task Units (TU) formed to provide the separate functions of the Task Group are also portrayed in Figure 1-2. A more detailed description of the Task Unit Organization is shown in Figure 1-3, Organization of Task Group 7.3. Where appropriate, each Task Unit was divided into Task Elements (TE). Figure 1-3 lists charge to destroy submerged enemy submarines without endangering itself? Specific answers to these questions were needed in order to plan possible naval use of these weapons.

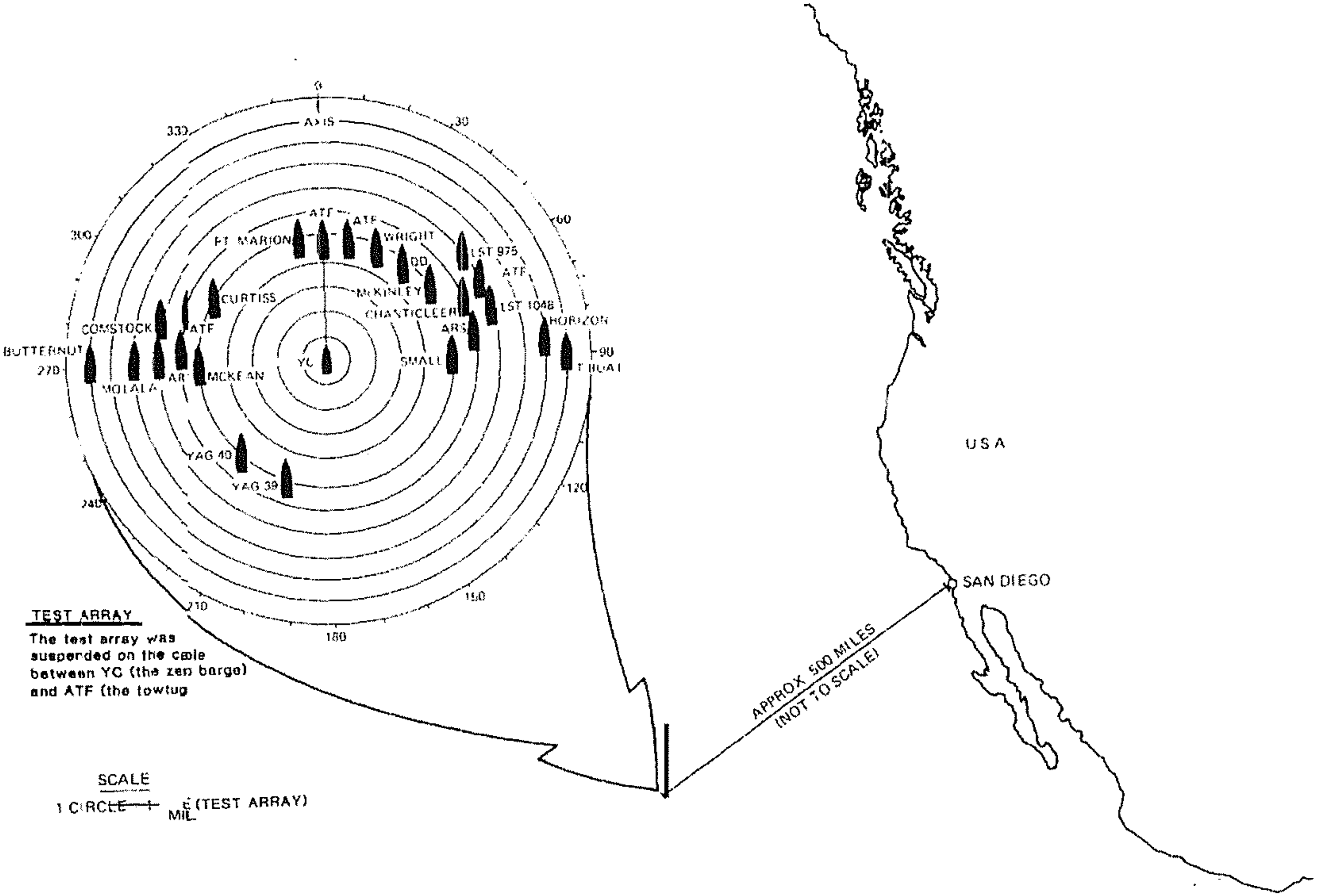
1-3 PURPOSE OF OPERATION WIGWAM.

Operation WIGWAM was a single shot nuclear weapons test carried out at 1300 PDT on 14 May 1955 at 126° 16' W and 28° 44' N about 500 miles SW of San Diego, California. (See Figure 1-1.) Operation WIGWAM included the following objectives:

- o To determine the fatal range of a deeply detonated nuclear weapon for a typical well-designed, modern submarine
- o To determine the pressure-time field in water and in air resulting from such an explosion
- o To determine the safe range for a surface ship in the vicinity of this detonation
- o To determine the fallout and contamination problems resulting from the explosion
- o To determine the characteristics of any additional phenomena which may occur as a result of the explosion.

1-4 AUTHORITY.

The initial studies and planning for a deep underwater shot were conducted over several years prior to Operation WIGWAM. Planning culminated on 8 December 1954 in a joint AEC/DoD request to the President seeking approval to expend the fissionable material in the device to be tested during Operation WIGWAM. Presidential approval was granted on 9 December 1954 (Reference 1). The AEC and DoD jointly passed the authority to conduct the exercise through organizational channels to a joint task group, which is discussed below in detail.



TEST ARRAY

The test array was suspended on the cable between YC (the zero barge) and ATF (the towtug

SCALE

1 CIRCLE — 1 MILE (TEST ARRAY)

Figure 1-1. WIGWAM Shot Location in the Pacific and Configuration of Task Force Vessels at Shot Time

> low-level ionizing radiation. The final NTPR report will be principally personnel-oriented (although it will contain appropriate background information on the shot itself), and I plan to make it available to CDC and other organizations to conduct follow-up studies."

In addition to its use as an instrument in scientific research, this report may also serve individual veterans, various government agencies, and the public as a historical account of Operation WIGWAM. As such, it can be used as an unclassified reference by anyone who wishes to learn more about that nuclear test. This volume is as complete as it can be made through an extensive research effort.

1-2 HISTORICAL BACKGROUND.

Throughout the years 1945-1962, the United States conducted nine nuclear weapons tests series in oceanic areas. Bikini and Enewetak Atolls, Johnston Island, and Christmas Island are well-known sites of such tests. During 1955, the first deep underwater nuclear weapons test, Operation WIGWAM, was conducted in an area of the Pacific Ocean situated approximately 500 miles southwest of San Diego, California. Figure 1-1 shows the approximate area of the test point and a diagram of the array of ships assembled for the test.

Prior to WIGWAM, nuclear weapons had been tested in the atmosphere, on the surface of the earth or water, or at a shallow underwater depth. A great deal of interest had developed, particularly within the U.S. Navy, in detonating a weapon at a sufficient depth to contain all the initial energy of the nuclear explosion in the water, to investigate deep underwater effects.

The Navy was interested in learning how such a deep underwater shot would affect naval forces. The two leading questions were: (1) what are the characteristics and lethal ranges of the resulting underwater shock wave, and (2) what are the effects of the radioactivity, following the explosion, on naval tactical operations? For example, could a surface vessel use a nuclear depth

In a memo to the Director of DNA, the Assistant Secretary of Defense* listed some of the tasks necessary to implement the NTPR program.† Based on this memo, DNA has taken the following responsibilities.

- o Develop a history of every atmospheric nuclear event that involved DoD personnel
- o Identify the radiation monitoring control policies, procedures, and requirements that were in effect for DoD personnel
- o Assemble a census of DoD personnel at each event/series
- o Determine a measured or estimated exposure for each DoD participant identified.

To fulfill the first two tasks, the DNA plans to produce reports of two types: series reports which will describe an entire series of nuclear test shots; and shot reports which will be devoted to one or a few especially interesting shots in a series. This volume is organized as a series report. However, since there was only one nuclear detonation in the operation, this report also serves as a shot report. The last two tasks require the development of a data base, which is described in Chapter 5. This is being published in a companion volume. The two products will be complementary, with the reports providing background information for the statistical analysis of the data base.

This dual effort is described more fully in a letter written by the Director of DNA:§

> "Currently, I visualize the final product of the NTPR effort to be a series of volumes covering all atmospheric nuclear tests. Although many reports and documents addressing these tests have already been written, they were oriented variously to test description, to the performance of the nuclear device itself, to nuclear effects on material, to troop maneuvers, etc. Few, if any, of these reports were concerned primarily with exposures of participating individuals to the effects of

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*For Manpower, Reserve Affairs, and Logistics.

†This memo is reprinted in Appendix A.

§This letter was addressed to the CDC and to the National Academy of Sciences.

CHAPTER 1
INTRODUCTION

1-1 PURPOSE OF THIS REPORT.

The discussions in this report are specifically designed to describe the participation of Department of Defense (DoD) personnel in the underwater nuclear weapons test WIGWAM, the only shot in the WIGWAM series. These discussions are arranged in the following manner. The historical background provides the underlying factors which established the need for conducting the test. Personnel involvement, with respect to organizational position or sponsoring agency, is described in the section on the organization of Operation WIGWAM. The Radiation Safety chapter focuses on both the organization and the procedures used to limit personnel exposure to ionizing radiation throughout the operation. The various activities of the participating agencies which may have exposed personnel to ionizing radiation are delineated in the Operations chapter. The Personnel Exposures chapter identifies the units which had the opportunity for exposures at WIGWAM and those which did not. This chapter also evaluates the extent to which the units were exposed. The Personnel Data Base chapter describes how personnel identification and exposure information are collected for inclusion in a separately published list of nuclear weapons tests participants.

The interest in DoD personnel involvement at nuclear weapons tests began in 1977, when the Center for Disease Control (CDC) identified a possible leukemia cluster among DoD participants in a nuclear weapons test conducted by the Atomic Energy Commission (AEC) at the Nevada Test Site during 1957. In response to this discovery, the DoD initiated the Nuclear Test Personnel Review (NTPR) program, with the Defense Nuclear Agency (DNA) acting as the executive agency.

have been lost or destroyed over the years. Other records have been transferred from one repository to another, and accounts of the transfer of documents are not always available.

The documents available provided the information necessary to complete this volume.

The National Academy of Science (NAS) and the CDC will then analyze this information to determine if there is a higher-than-normal incidence of disease among the test participants, and, if so, if it might be related to exposure to low-level ionizing radiation.

This report on Operation WIGWAM is based on the military and technical documents associated with that atmospheric nuclear weapon test. It provides a public record of the activities and associated exposure risks of DOD personnel for use in ongoing public health research and policy analysis.

Many of the documents pertaining specifically to DOD involvement during WIGWAM were found in the Modern Military Branch of the National Archives, the Defense Nuclear Agency Technical Library, and Air Force Weapons Laboratory Technical Library. Frequently, the Surviving historical documentation of activities conducted during Operation WIGWAM addresses test specifications and technical information rather than the personnel data critical to the study undertaken by the Department of Defense. Moreover, instances have arisen in which available historical documentation has revealed inconsistencies in vital factual data. These inconsistencies in data usually occur between two or more documents, but occasionally appear within the same document. Efforts have been made to resolve these data inconsistencies wherever possible, or to otherwise bring them to the attention of the reader.

Gathering data for this volume presented a variety of challenges. Teams of historians, health physicists, radiation specialists, and information analysts canvessed document repositories known to contain material on atmospheric nuclear weapons tests conducted at sites in the United States and in the Atlantic and Pacific Oceans. The teams examined classified and unclassified documents containing information on DOD participation in Operation WIGWAM. Many different military and civilian organizations were involved in developing and storing records related to Operation WIGWAM. Each branch of the Armed Services and each civilian organization had its own system of recording information. Some records

PREFACE

From 1945 to 1962, approximately 2 3 5 air, surface, underground, and underwater nuclear weapons test were executed under the auspices of the Atomic Energy Commission (AEC), now incorporated within the Department of Energy (DOE) and the Department of Defense (DOD). The primary purposes of these tests were to verify the principles of nuclear weapons design and to determine the effects of nuclear weapons on both military and civilian targets. In all, an estimated 220,000 Department of Defense participants, both military and civilian, were present at the tests.

In 1977, the Center for Disease Control (CDC)* identified a possible leukemia cluster among DOD participants in a nuclear test (SMOKY) conducted in 1957 at the Nevada Test Site. As a result of this discovery and renewed concern over the health effects of low-level ionizing radiation, the Department of Defense began a study which provided data to both the CDC and the Veterans Administration (VA) on potential exposures to ionizing radiation among the military and civilian personnel who participated in the atmospheric testing 15 to 30 years earlier. DOD study effort was extended to:

- o Identify DOD personnel who had taken part in the atmospheric nuclear weapons tests.
- o Develop a history of each atmospheric nuclear event involving DOD personnel.
- o Identify the radiation monitoring control policies, procedures and requirements which were in effect.
- o Determine the extent of the participants' exposure to ionizing radiation.
- o Provide public disclosure of information concerning participation by DOD personnel in the atmospheric nuclear weapons tests.

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*The Center for Disease Control is part of the U.S. Department of Health and Human Services (formerly the U.S. Department of Health, Education and Welfare).

SYNOPSIS OF WIGWAM

AEC Test Series:	WIGWAM
Test Name:	WIGWAM
Date/Time:	1300 Hrs PDT, 14 May 1955
Yield:	30 KT
Depth of Burst:	2000 ft. beneath surface, Pacific Ocean
AEC Objectives:	Weapon Development, output measurements
DoD Objectives:	Determine lethal distances for nuclear effects vs. submerged submarine hulls. Evaluate tactics for delivery of nuclear weapons against deep-submerged submarines.
Weather:	Wind from north about 18 knots, 7/8 cloud cover with ceiling below 5000 ft.
Military Units:	Joint Task Group 7.3, 30 ships including target array and ships from Scripps Institution of Oceanography.
Number of DoD Participants:	Personnel listings from ships and agencies involved total 6,544 participants. Approximately 200 were non-DoD, therefore it is estimated that 6,344 DoD personnel were present.
Radiation Exposure History:	All personnel were on ships located at least 5 miles from the surface point above the detonation (surface zero). All prompt radiation was absorbed by sea water. Bubble reached surface with some airborne contamination. About 91% of participants received no radiation exposure. Highest radiation exposure for any individual: 0.425 R.

WIGWAM EXPOSURES

			Exposures expressed in roentgen (R)				
	Total Issued	Dosimetry Unavailable	Zero Exposure	.100-.165	.200-.280	.315-.385	.425
Badges	6,732	229	6,141	329	19	13	1*
% in each group	100%	3.4%	91.2%	4.9%	0.3%	0.2%	0.01%

*The highest exposure was received by a member (an air sampler pilot) of the aviation support provided through Naval Air Station, San Diego.

The average exposure for the 362 WIGWAM individuals with non-zero exposures was 0.129 R, which is about the average annual exposure to naturally occurring background radiation in the United States.

Data compiled at the time of the test indicated that operational badges showed 350 positive recorded gamma exposures with a maximum reading of 0.425 R. This earlier compilation indicated that the average exposure for these 350 badges was 0.132 R. Although the results of the two data reviews differ slightly, they both confirm that more than 90 percent of all doses at WIGWAM were zero and that recorded exposures at WIGWAM ranged from 0.100 R to 0.425 R.

The two vessels (YAG-39 and YAG-40) stationed downwind of the detonation point were subjected to contamination by water droplets of the base surge. None of the YAG personnel received significant exposures. Both of these vessels had been specially configured and shielded for the purpose of crossing contaminated areas although only YAG-39 had a seawater washdown system. The deck surface radiation reading on YAG-39 reached levels in excess of 400 R/hr about 17 minutes after the detonation. The washdown system that had been installed to decontaminate the surfaces reduced this level to 0.040 R per hour 30 minutes after the detonation. Recorded shipboard levels were less aboard YAG-40. Both of these vessels had 48 assigned personnel. However, at the time of detonation only about 12 crewmembers and project personnel were aboard each YAG. Six crewmembers aboard YAG-39 and one crewmember aboard YAG-40 received recorded exposures other than zero. In each instance, recorded film badge readings for crewmembers did not exceed 0.130 R. One unidentified, non-crewmember aboard YAG-40 received an exposure of 0.200 R.

back into the water, a large cloud of mist was formed. This was the base surge which at H + 90 seconds, had a radius of 4,600 feet and a maximum height of 1,900 feet. The visible surge persisted to H + 4 minutes. At H + 13 minutes, a foam ring appeared with a 10,400 foot diameter. The area within this ring probably approximated the extent of the contaminated water. While the surface water initially showed significant contamination levels, the water dispersed and radiation decayed rapidly, so that by May 18 the maximum radiation reading found over an 80 square mile area was on the order of one milliroentgen per hour (mR/hr) at 3 feet above the surface. Contaminated water was found at several depths during the weeks following the test and tended to be in layers a few feet thick.

Radiation Safety Procedures

Radiological safety was a paramount consideration of the operation and overall was the responsibility of the US Naval Radiological Defense Laboratory (NRDL). Radiation Safety (Rad-safe) procedures included measures to minimize exposures to personnel, to measure and evaluate radiological hazards and contaminated areas, to control exposures to personnel and the spread of radioactive contamination from samples, equipment and other materials, and the documentation of levels of exposure and contamination. For the duration of the operation, an exposure limitation of 3.9 roentgen (R) was set. In addition, levels were specifically established for radioactive contamination of clothing and personal equipment, food, water, air, ships' surfaces, equipment and materials.

An important part of the Rad-safe procedures was the personnel dosimetry program. Nearly all individuals involved in the operation were issued a film badge to measure any exposure received during the operation. Personnel whose duties were such that exposure to radiation was possible (such as sampling water, recovering equipment or instruments) were issued additional film badges on a daily basis. One of the vessels, the USS WRIGHT, contained a film processing center where badges were read and personnel exposures were recorded. Over the period of the operation, approximately 10,000 film badges were issued. There included operational, daily, calibration, and scientific project badging.

Personnel Exposures

The rad-safe procedures established for the operation were highly effective in keeping personnel exposures to a minimum. The following table summarizes the recorded personnel radiation exposures at WIGWAM based upon a 1979 review of dosimetry:

Fact Sheet

Defense Nuclear Agency
Public Affairs Office
Washington, D C 20305

Operation WIGWAM

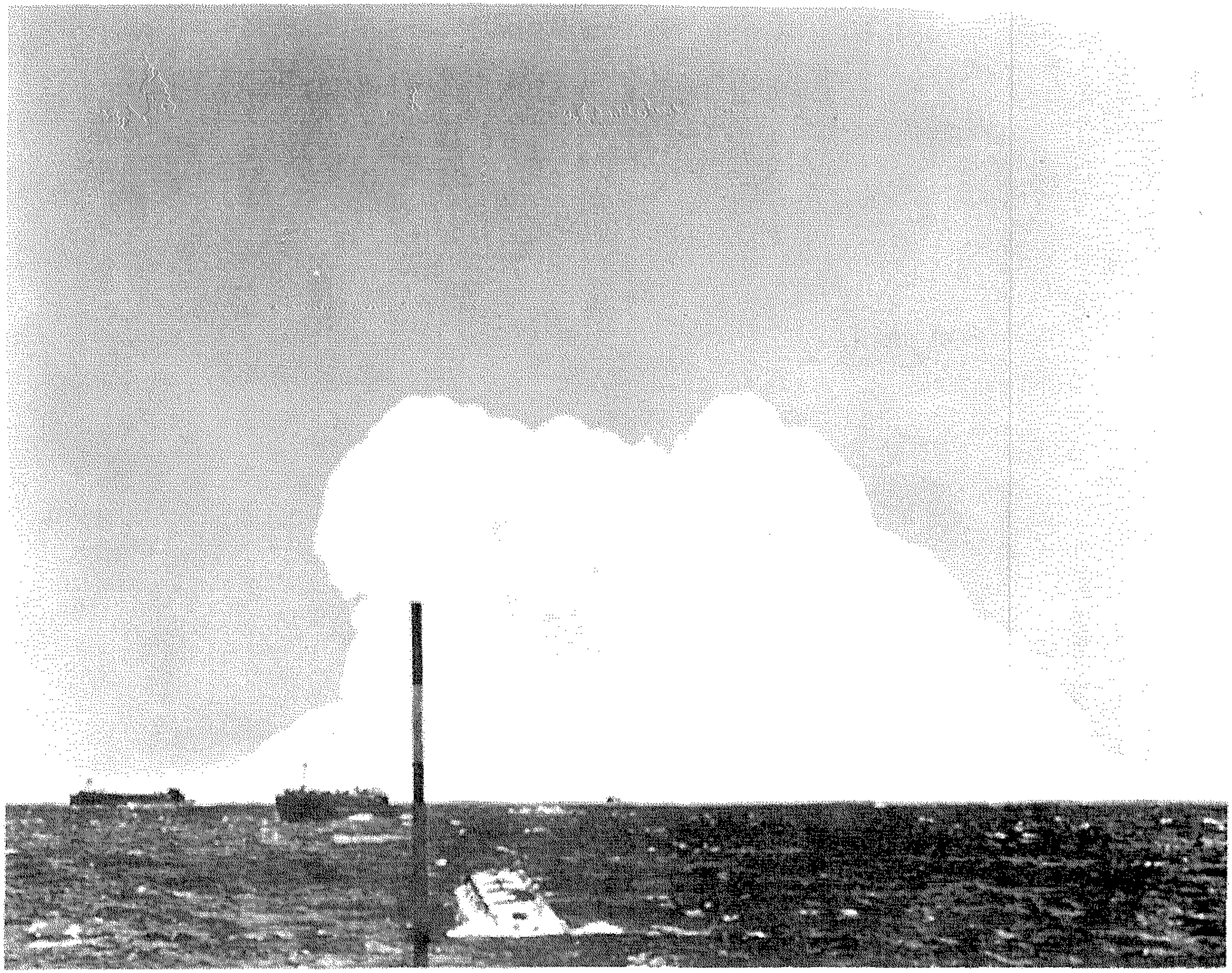
Operation WIGWAM was a deep underwater nuclear test conducted as part of the 1945-1962 United States series of atmospheric nuclear tests. It took place in May 1955 in the Pacific Ocean approximately 500 miles southwest of San Diego, California, under the joint administration of the Atomic Energy Commission and the Department of Defense (DoD). The purpose of the operation was to determine the radiation and pressure phenomenology associated with nuclear detonations at great depths and to ascertain the effects such explosions would have on submerged and surface vessels. Approximately 6544 personnel and 30 ships took part in this operation under the Commander, Joint Task Force Seven.

Test Array

A single, 30-kiloton nuclear device was suspended by cable from a towed unmanned barge to a depth of 2000 feet in water that was 16,000 feet deep. Located at varying distances along the approximately six-mile (30,000 feet) long towline between this barge and the fleet tug, USS TAWASA (ATF-92), were a variety of pressure-measuring instruments, unmanned and specially prepared submerged submarinelike hulls (called squaws) as well as instrumented and also unmanned surface boats. The ships and personnel conducting the test were positioned five miles upwind from the surface detonation point with the exception of USS GEORGE EASTMAN (YAG-39) and USS GRANVILLE S. HALL (YAG-40). These two extensively reconfigured ships, equipped with special radiological shielding, were stationed five miles downwind of the surface detonation point. With all the ships at their assigned stations and all personnel accounted for, the device was detonated at 1:00 P.M. Pacific Daylight Time on May 14, 1955.

Radiation Contamination

WIGWAM resulted in three sources of radiological contamination: airborne activity, residual fallout and water contamination. During the first three seconds after the detonation, the radioactive debris was primarily contained within an initial bubble formed by the interaction of thermal energy with the water. Then, beginning at approximately H + 10 seconds (ten seconds after the detonation) these gaseous products began to reach the water surface, forming spikes and plumes reaching maximum heights of 900 to 1,450 feet and emerging from an area roughly 3,100 feet in diameter. As the plumes fell



TABLES

TABLES

ILLUSTRATIONS

ILLUSTRATIONS

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Table E-Z. Detector range and response (Reference 6).

	Response in sec*				
Field, R/h	Am	Bm	Cm	Dm	Em
0.001	3.600				
0.002	1,800				
0.005	720				
0.010	360	3,600			
0.020	180	1,800			
0.036	100	1.000			
0.050	72	720			
0.100	36	360	3,600		
0.200	18	180	1,800		
0.360	10	100	1.000		
0.500	7.2	72	720		
1.00		36	360	3.600	
2.00		18	180	1,800	
3.60		10	100	1,000	
5.00		7.2	72	720	
10.0			36	360	3.600
20.0			18	180	1,800
36.0			10	100	1.000
50.0			7.2	72	720
100				36	360
200				18	180
360				10	100
500				7.2	72
1,000					36
2,000					18
3.600					10
5,000					7.2

Note: Am, Bm, Cm, Dm, and Em are designations for continuous gamma recorders, each set for different ranges as shown above.

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*"Response in seconds" is the time lapse between each recorder pulse mark on a continuous roll of data paper.

APPENDIX E
RADIOLOGICAL INSTRUMENTATION
(Continued)

E-2 AERIAL SURVEY (Reference 6).

The gamma detector used in the aerial surveys employed both gamma radiation sensitive plastic phosphors and photomultiplier tubes. The total range was divided into four scales with ranges from 0.005 to 1.0 mR/h, 0.1 to 100 mR/h, 0.01 to 10 R/h, and 1.0 to 1000 R/h, respectively. The results of the survey flights were extrapolated to an altitude of 3 feet as shown in Figure E-1. It is suggested in Reference 6 that the radiation intensities reported for the 3-foot altitude on D-Day, for the survey flights at 500 feet, may have been too high by approximately 50 percent. The subsequent readings made from the 200-foot altitude may then be 25 percent too large.

E-3 PROJECT 2.6 (Reference 7).

Project 2.6, fielded by the Scripps Institution of Oceanography, used the ship Horizon as a platform for studies on the dispersion of radioactive material in the ocean. Deep drogues, samplers, and Geiger counters in sondes provided much of the experimental material and data pertaining to the radiological contamination of the ocean for the Project. Gamma spectra analyses were conducted on the Baird (also a Scripps ship) using a scintillation counter.

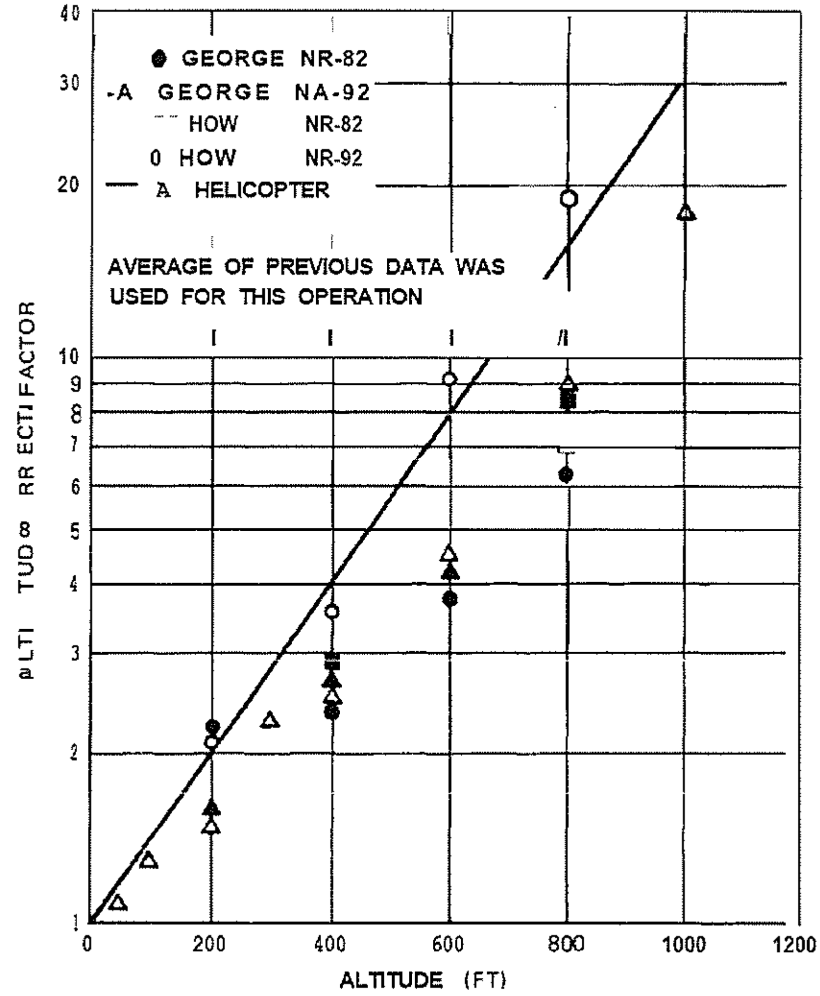

Figure E-1. Comparison of altitude correction factors on D+1.

APPENDIX F

MAXIMUM PERMISSIBLE LIMITS (MPLs)

(Extract from Reference 4 pp. 63, 64)

1. Maximum Permissible Exposures (MPEs) for Personnel

	Radiation Exposure Gamma, R	Beta, rep
Whole Body	3.9	10
Hands and Feet	20	20

2. Maximum Permissible Concentrations (MPCs)

a. MPCs for personnel

Skin contamination: fixed beta-gamma, 1,000 c/m[*] (max)

Airborne activity: respiratory devices are required if the airborne fission-product concentration is in excess of the following:[†]

Days After Detonation	Concentration (beta-gamma), pc/cc of air[§]	Total Permissible Period of Exposure
0.1	2.7×10^{-5}	1 day
1	1.7 x 10-7	1 day
2	1.2 x 10-7	1 day
4	9.9×10^{-8}	1 day
7	7.9×10^{-8}	1 day
14 to 28	1.0 x 10-8	2 weeks

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[*] c/m = CPM

[†] From the proposed revision of Rad-Safe regulations, NavMed P-1325, October 1954.

[§] pc/cc = pCi/cm^3

APPENDIX F
MAXIMUM PERMISSIBLE LIMITS (MPLs)
(Extract from Reference 4 pp. 63, 64)
(Continued)

Exposure to airborne alpha contamination shall not exceed 10^{-11} c/cc* of air.

3. Food and drinking water: food and water contamination with fission-product material in excess of the following value shall not be consumed.

Days Following Detonation	Contamination (beta-gamma), c/cc of water or c/g of food	Maximum Permissible Period of Ingestion
0.1	7 x 10-f	1 day
1	4.8 x 10^{-3}	1 day
2	2.1 x 10-3	1 day
4	9.2 x 10-4	1 day
7	4.7 x 10-4	1 day
14 to 28	1.0 x 10-4	1 week

Food and water should not be ingested if alpha contamination is present in excess of 10^{-7} c/g or c/cc.

b. MPCs for clothing

Personal

General clothing, 1,000 c/m fixed beta-gamma

Shoes, 5,000 c/m fixed beta-gamma

Rad-Safe clothing

Re-issue

Coveralls, etc., 5,000 c/m fixed beta-gamma

Gloves, shoes, etc., 25 mrep/hr, 50,000 c/m fixed beta-gamma

Controlled use

Coveralls, 50,000 c/m

Gloves, shoes, 25 mrep/hr

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*c/cc = Ci/cm^3

APPENDIX F

MAXIMUM PERMISSIBLE LIMITS (MPLs)

(Extract from Reference 4 pp. 63, 64)

(Continued)

c. MPCs for equipment

Final clearance (no further Rad-Safe control)
Fixed beta-gamma, 5,000 c/m

Operation clearance (Rad-Safe Control continues)
Fixed beta-gamma, 50,000 c/m
Removable beta, 5,000 c/m/12 sq. in.

d. Sample shipments (packaging requirements)
Radiation level (exterior of container), f r/hr
Removable contamination, 500 c/m/12 sq. in.

COPY

APPENDIX G

RADIOLOGICAL SAFETY PLAN

(These extracts from the Task Group 7.3 Operation
Plan 1-55 describe the plan adopted for Rad-Safe.)
Extract from Annex G, TG 7.3 Operation Plan 1-55

1. General

a. Radiological safety of task group military and civilian personnel is a command responsibility and radiological safety activities will be performed through normal command channels.

b. Radiological Safety (Rad-Safe) operations is a general term which denotes the means by which a unit attempts to prevent the occurrence of hazards to personnel and equipment resulting from the spread of radioactive material. With this end in view it includes such measures as training, organization and distribution of certain personnel; development of techniques and procedures for use of radiological detection equipment; protection or removal of exposed personnel; and decontamination of personnel, structures and equipment.

c. Following the detonation there will be areas of surface radiological contamination and, possibly, limited areas of aerial radiological contamination.

2. Mission

The purpose of the radiological safety organization is to provide:

a. Protection of personnel and equipment

b. Effective training of personnel

c. Evaluation of the effectiveness of radiological safety training and radiac equipment

COPY

APPENDIX G
RADIOLOGICAL SAFETY PLAN
(Continued)

3. Phases

To carry out its mission, the radiological safety operations of Task Group 7.3 during Operation WIGWAM are divided into three phases:

a. Preshot phase

b. Shot phase

c. Rollup phase

4. Preshot Phase General Requirements

a. The preshot phase will be utilized by all subordinate commands in:

1) Developing operational efficiency to carry out all phases of Rad-Safe through training.

2) Filling of operation equipment allowances.

3) Maintenance and calibration of radiac equipment

4) Establishment of personnel decontamination facilities

b. Developing operational efficiency.

1) Rad-Safe training of certain individuals.

2) Rad-Safe training of crews.
This training will be accomplished in conformance with applicable instructions from administrative commanders.

c. Maintenance and calibration of radiac equipment.

Each ship will require its entire allowance of radiac equipment in good operating condition. Units of Task Group 7.3 are responsible for the maintenance of their own radiac equipment. For calibration and repairs beyond the capacity of ship's force, assistance can be obtained from the Radiac Repair Facility, San Diego (corner Vesta and Main Streets, telephone Belmont 2-6911, Ext. 1118) when in port and from the Task Group Rad-Safe Project Officer on board the USS WRIGHT (CVL-49) at other times. Failure report cards and equipment history cards shall be used with all radiac instruments. Each unit shall depart for the forward area with not less than 100% spare batteries for radiac instruments. These batteries should be ordered as early as practicable, as some are in short supply.

d. Personnel Decontamination Facilities

Decontamination stations as described in NWIP 50-1, NavPers 10886, and applicable instructions from administrative commanders shall be in operating condition on each ship to permit showering and monitoring exposed personnel. Fabrication of these facilities is considered to be within the capability of ship's force.

5. <u>Shot Phase General Requirements</u>

a. If ships of the task group are contaminated by personnel or material coming on board, every effort shall be made to localize the contamination.

Standard decontamination procedures as outlined in NWIP 50-1, Nav Pers 10886 and Appendix II of this annex shall be used to remove contamination.

b. Decontamination of personnel and disposal of contaminated material shall be as provided in Pacific Fleet Instructions, NWIP 50-1, NavPers 10886, and Appendix D-II to this annex.

COPY

APPENDIX G
RADIOLOGICAL SAFETY PLAN
(Continued)

6. Rollup Phase General Requirements

a. All subordinate commands in TG 7.3 shall make the following reports by letter to CTG 7.3 and mail these reports in the first port entered after the operation, not later than 3 working days after entering port.

1) Instances of contamination of either personnel or equipment covering the following: time after shot when first noticed, intensity, type of radioactivity encountered, estimated initial time of contamination, methods of decontamination, effectiveness thereof, and final disposition of contaminated items.

2) Radiac equipment performance, adequacy of spares, etc. Such reports should include operational difficulties in use of equipment and an estimate of the adequacy of personnel training methods.

3) That all radiac instruments borrowed from the Rad-Safe Project Officer have been returned, or exception, if any.

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APPENDIX G

(Extracts from Appendix I to Annex G, TG 7.3
Operation Plan 1-55)

RADIOLOGICAL SAFETY REGULATIONS

1. General

The Maximum Permissible Exposures (MPEs) and Maximum Permissible Concentrations (MPCs) as stated herein are applicable to a field experimental test of a nuclear device in peacetime wherein numbers of personnel engaged in these tests have been previously exposed or may be continuously exposed to potential radiation hazards. The regulations set forth herein are considered to be reasonable and safe. They are designed to minimize personnel exposures with due regard to the importance of the test and the cost aspects of operational delay occasioned by excessive radiological precautions. Special instances may arise such as in the case of air-sea rescue, or in the case of a tactical situation, in which operations will be carried out without regard to the MPEs and MPCs prescribed herein. For such emergency or tactical operations the criteria prescribed below for tactical situations will be used as a guide. Film badges will be carried and Rad-Safe monitors will accompany such operations to determine the extent of the actual radiation hazard experienced in order that appropriate medical action may be initiated.

2. Maximum Permissible Exposure

a. The MPE for personnel involved in this operation is 3.9 roentgens (gamma only). This exposure may be acquired at any time during the operation, and may be acquired without regard to the individual's past radiation history unless there has been previous over-exposure requiring continuing compensation.

b. A special MPE of 20 roentgens (gamma only) is authorized for the duration of the operation for personnel engaged in collection and handling of critical water samples necessary for yield determination. These personnel will number approximately ten, and will be designated by CTG 7.3 prior to the operational period.

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APPENDIX G
RADIOLOGICAL SAFETY REGULATIONS
(Continued)

c. Beta radiation exposure to the hands should not exceed 30.0 rep for the operational period.

d. The MPEs are subject to revision by waiver from the Task Group Commander in individually designated cases when circumstances indicate a need and justification therefor.

e. All exposure to film badges worn on the body torso will be regarded as total body irradiation.

3. Maximum Permissible Concentrations (MPCs)

Maximum Permissible Concentrations (MPCs) are not to be confused with MPE's (see paragraph 2 above) or with Final and Operational Clearances (see paragraph 5 below). MPCs listed herein are to be regarded only as advisory limits for control under average conditions, and may be exceeded by a task unit commander when in his opinion this action is justified. Task unit commanders must use their judgment to "get the job done" and also stay within the MPE specified in Paragraph 2a above. Contamination should be reduced and maintained as low as practicable consistent with "getting the job done."

a. Personnel and clothing MPCs are as follows:

1) Contamination on the skin should be removed by thorough scrubbing until skin readings are as low as practicable. In general, it is not considered profitable to abrade the skin or scalp in an attempt to reduce stubborn contamination below 1 mr/hr (gamma only). In cases where skin contamination cannot be readily reduced to 1 mr/hr (gamma only) by bathing, the ship's Rad-Safe Officer should be contacted for guidance.

APPENDIX G
RADIOLOGICAL SAFETY REGULATIONS
(Continued)

2) Contamination on underclothing and body equipment such as the internal surface of respirators should be reduced as low as practicable, and to a value lower than 2 mr/hr (gamma only).

3) Contamination on outer clothing should be reduced as low as practicable, and to a value lower than 7 mr/hr (gamma only).

b. Ship, Boat and Aircraft MPCs

1) It is desired to point out that the employment of the ships and units in TG 7.3, insofar as radiological safety is concerned, is not considered routine usage within the purview of NavMed P-1325 , "Radiological Safety Regulations." For WIGWAM, naval personnel are operating under regulations set forth by the Task Group Commander as approved by the Chief of Naval Operations.

2) Ships, boats, and aircraft operating in or over waters near the shot point after shot time may become contaminated. Monitors shall be aboard all such craft operating after shot time, either as passengers or members of the crew, until such time as radiological restrictions are lifted.

3) Task unit commanders shall take necessary action to ensure that personnel of ships, boats, and aircraft are not over-exposed to radiation and that ships, boats, and aircraft are not contaminated excessively. The criterion is that, except in emergencies or tactical operations, no personnel

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APPENDIX G
RADIOLOGICAL SAFETY REGULATIONS
(Continued)

shall be over-exposed as defined by Paragraph 2 above, and no ship, boat or aircraft shall be contaminated to the degree that personnel aboard them receive more than 0.3 roentgens (gamma only) per week after the operational period.

4) For ships, boats, and aircraft operating in or over contaminated waters, reasonable allowances shall be made to differentiate between the relative contribution to the total flux from fixed contamination and that due to "shine" from contaminated waters.

5) Alpha contamination is not expected to be a problem. If it is, special instructions will be promulgated.

6) Contamination on ships, boats, and aircraft shall be reduced as much as practicable, and except in unusual cases to a value lower than 7 mr/hr (gamma only). A surface is not decontaminated sufficiently when two square inches of filter paper rubbed lightly over twelve square inches of the contaminated surface and then held one-half inch from the open window of an AN/PDR-27 type instrument read more than 0.5 mr/hr above background. Advice can be obtained from the staff of CTG 7.3.

7) When a ship or boat is in contaminated water for an appreciable period of time, some of the contamination becomes attached to the hull and interior of the salt-water systems. There is only a very slight probability that this problem will be serious on any ship except the YAG. This type of

APPENDIX G

RADIOLOGICAL SAFETY REGULATIONS

(Continued)

contamination entails no internal, beta, or alpha hazard to people aboard, but only an external gamma hazard. In general, decontamination of this type of contamination will not be practicable or necessary during Operation WIGWAM. This type of contamination can be minimized by keeping vessels in contaminated water only as long as necessary for the accomplishment of their missions. After the detonation, each ship other than the YAG's shall be monitored for radioactivity every 4 hours, or oftener if considered advisable by the commanding officer, until leaving the vicinity of the detonation, with special attention to evaporators and condensers. Commanding officers shall notify CTG 7.3 promptly of any cases where it appears that contamination of this type may result in exposure of personnel to more than 1 roentgen during the operation. Estimates of exposure should be realistic; for example, if an engineering space has an intensity of 50 mr/hr one inch from a condenser, and 2 mr/hr at a place 10 feet from the condenser where a man stands watch 8 hours per day, the estimated exposure of this man is 2 x 8 = 16 mr/day and not 50 x 8 = 400 mr/day.

4. Tactical Situations*

In tactical situations the OTC must make the decision regarding allowable exposures, and the MPEs described above do not apply. As military personnel are normally subject to only random exposure, health hazards are a

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* NTPR Note: This paragraph applies not to normal WIGWAM operations but to "tactical" (nuclear war) operations and "emergency" (rescue) operations (such as helicopter crash in highly contaminated water).

minimum. Current Department of Defense information on exposure to gamma radiation in tactical situations is indicated below:

a. Uniform acute (immediate) exposure of 50 roentgens to a group of Armed Forces personnel will not affect their efficiency as a fighting unit.

b. Uniform acute exposure of 100 roentgens will produce occasional nausea and vomiting in individuals, but not to an extent that will render Armed Forces personnel ineffective as fighting units. Personnel receiving acute radiation exposure of 100 or more roentgens should be given a period of rest and individual evaluation as soon as possible.

Uniform acute exposure of approximately 150 roentgens or greater can be expected to render Armed Forces personnel ineffective as troops within a few hours through a substantial incidence of nausea, vomiting, weakness and prostration. Mortality produced by an acute exposure of 150 roentgens will be very low and eventual recovery of physical fitness may be expected.

d. Operational commanders should, therefore, assume that if substantial numbers of their men receive acute radiation exposures substantially above 100 roentgens there is a grave risk that their commands will rapidly become ineffective as a fighting unit.

e. Internal hazards following a contaminating underwater explosion may be avoided if ordinary sanitary precautions are taken, such as washing the face and hands before eating. Only under unusual circumstances will there be internal hazard from residual contamination.

f. The aircraft controller in a tactical situation shall make every effort to keep planes clear of aerial contamination to the maximum extent allowed by the tactical situation.

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APPENDIX G
RADIOLOGICAL SAFETY REGULATIONS
(Continued)

5. Final and Operational Clearance

At the conclusion of the operation, final clearances will be granted by the Task Group Commander, or by commanding officers if so ordered, to those ships, boats, and planes showing no point of contamination greater than 15 mr/day (beta and gamma) and no detectable alpha. Other craft will be granted operational clearances by the Task Group Commander, or by commanding officers if so ordered. An operational clearance implies that contamination exists and that special procedures as necessary are instituted on board ship.

6. Duties of Monitors

Rad-Safe monitors assigned during recovery operations shall act in an advisory capacity to keep the persons in charge of recovery operations informed of radiation intensities at all times. The persons in charge shall accept this advice and act accordingly. It is the responsibility of the person in charge to adhere to the limits established in these regulations. The Rad-Safe monitor shall limit his activities to monitoring and will not engage in actual recovery operations.

7. Film Badges

a. Film badges shall be worn by all personnel. A film badge shall be issued to each individual to be worn during the entire operation. Each of these badges will be processed at the conclusion of the operation to give the official integrated radiation dosage for the legal-medical records. In addition, personnel expected to receive significant radiation will be issued additional film badges to be processed on a daily basis so that immediate checks can be made on the rate of dosage accumulation and the possibility of over-exposures minimized.

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b. All personnel shall be cautioned to wear their film badges at all times, to avoid losing them, and to avoid ruining them by laundering or other methods.

c. Additional film badges, dosimeters and protective clothing (coveralls, booties, caps, gloves, etc.) as deemed necessary shall be issued to personnel expected to receive significant radiation and/or contamination by appropriate task group Rad-Safe supply sections. All personnel dosage film badges shall be procured from and returned to representatives of the laboratory on board the WRIGHT where all processing and recording will be accomplished. No other personnel dosage film badges shall be used during this operation.

d. Detailed instructions for issue and return of film badges will be promulgated separately.

8. Exposure Records

The Rad-Safe Project Officer will maintain standard type film badge records of radiation exposures, for all task group personnel. Records will indicate full name, rank or rate, serial or service number, if applicable, organization, home station or laboratory, date of exposure, and remarks such as limitations on assignment because of exposure. Upon completion of the operation, disposition of these records will be as follows:

a. A consolidated list of exposures listing military personnel (and civilian personnel under military control) by full name, rank or rate, serial or service number (if applicable), organization, home station or laboratory and exposure in milliroentgens together with exposed film badges and control film badges will be forwarded to the Chief, AFSWP.

APPENDIX G
RADIOLOGICAL SAFETY REGULATIONS
(Continued)

b. A consolidated list of personnel and exposures will be forwarded to the Director, Division of Biology and Medicine, AEC.

C. Individual records of Navy military and civilian personnel will be forwarded to their unit of assignment for inclusion in the individual's health record (Medical History Sheets and NavMed H-8). Military personnel who have received an average of more than 0.3 roentgen (gamma only) per week since 1 January 1955 will be advised that they should not be exposed to further nuclear radiation until sufficient time has elapsed to bring their average radiation dose subsequent to 1 January 1955 down to 0.3 roentgen (gamma only) per week. Civilian personnel in this category will be informed that limitations on further radiation exposure will be as determined by the laboratory or agency having administrative jurisdiction over such personnel.

d. Upon completion of the above, letter reports from the Rad-Safe Project Officer will be submitted through channels to the Chief, Bureau of Medicine and Surgery, and the Director, Division of Biology and Medicine, AEC, indicating, in general, the action taken to dispose of individual dose records, comments on over-exposures, and any pertinent remarks considered of interest to the above offices.

9. Analysis of Drinking Water for Radioactivity

It has been found in a previous operation that distilled water from evaporators is uncontaminated even though the evaporators become contaminated to a level of 20 mr/hr one inch from the evaporators. The explanation is that contamination does not distill with the water, but part of it goes overboard with the brine and the remainder becomes attached to the scale and condenser. Nevertheless, any commanding officer may at his discretion send samples of drinking water to the Rad-Safe Project Officer on board the USS WRIGHT for an analysis for radioactivity.

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APPENDIX G

DECONTAMINATION PROCEDURES

(Extracts from Appendix II to Annex, G,
TG 7.3 Operation Plan 1-55)

1. General

Radioactive contamination will probably at some time during Operation WIGWAM render an essential area or piece of equipment temporarily unusable. In such a situation, the reduction of such radioactive contamination may be mandatory to successful accomplishment of the operation. Decontamination of units and personnel shall be accomplished on the site to reduce the hazard to operational levels. It should be remembered that radioactive fission products decay as time passes, the most rapid decay taking place within the first few hours after detonation. To compute dosages, see "Radiological Defense," Vol. II pp 223-229.

2. Reagents

In most of the decontamination operations which might be required of Task Group 7.3, uncontaminated fresh or salt water sprayed under pressure shall be used for gross decontamination. Ordinarily, salt water should not be used on aircraft. Other reagents which are used where water is inappropriate or inadequate are: soaps, detergents, standard cleaner USN C-152 or 147, 5-10% sodium citrate solution of USAF cleaning compound Spec. 20015 (gunk), kerosene and soap powders. Cleaners with an oil carrier are especially suitable for aircraft decontamination.

3. General Aircraft Decontamination Procedures

a. If it has been determined through monitoring that decontamination is necessary, aircraft will be decontaminated at a shore facility or on board the WRIGHT, as circumstances indicate.

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APPENDIX G
DECONTAMINATION PROCEDURES
(Continued)

1) Decontamination operations on board a carrier (general criteria).

In decontaminating aircraft on board a carrier, the following factors should be stressed:

a) Area should be well isolated from personnel living spaces, ventilator intakes, etc.

b) A clear watershed to the sea should be provided, if practicable, to prevent contamination of the vessel.

c) Air circulation.

2) Decontamination operations aboard a carrier (specific)

a) Decontamination personnel shall be in decontamination suits. Decontamination suits shall ordinarily include the following:

NOMENCLATURE	STOCK NO.
Coveralls	637-G-2570 (or equivalent)
Gloves	637-G-2295
Overshoes, Rubber N-1	U37-0-69150
Cap, Marine Utility	73-C-59100 through 59104 (or equivalent)

This decontamination suit provides protection from contamination, and, for avoiding heat prostration, is much more satisfactory than a waterproof suit. The Marine utility cap is preferred to the Navy utility cap N-1, because more adequate head coverage is provided.

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APPENDIX G
DECONTAMINATION PROCEDURES
(Continued)

b) Decontamination personnel shall be restricted to the immediate area surrounding the contaminated aircraft. Support personnel are in the "clean" background area to'manipulate equipment to the decontamination team.

c) The decontamination area should be clearly marked and roped off in some manner.

d) Every effort shall be made to prevent the contamination of the ship in the decontamination area.

e) Provisions should be made for disposal of contaminated items in the decontamination area (GI cans may be used for small objects).

f) All material leaving the decontamination area shall be monitored.

g) Decontamination operations shall be interrupted intermittently for monitoring of aircraft to determine effectiveness. Work periods should be calculated after intensity levels are measured.

h) Decontamination operations should continue until the level of intensity drops below 7 mr/hr (gamma only). If this level cannot be readily attained using the methods indicated herein, the Rad-Safe Officer TG 7.3 should be contacted for instructions.

i) Where metal parts are contaminated and there is danger of damaging adjacent items of porous material, such as fabric, scrubbing with cleaning solution is effective.

j) If initial contamination is driven into paint, apply a solution containing 5 pounds lye, 5 pounds boiler compound, 1 pound starch and 10 gallons of water and scrub with wire brush or scrape to remove all paint. Apply cleaning solution and flush thoroughly with water. REMONITOR.

4. General Ship Decontamination Procedures

a. Spraying of the topside with nonradioactive water following an unavoidable exposure of ship to radioactive fallout will probably minimize the necessity for further decontamination. The interior of the ship is preserved in its 'clean" status by setting of the appropriate damage control condition of readiness to seal the ship's envelope.

b. Should the above method fail to prevent contamination, decontamination suits shall be worn to protect the damage control parties who must work on the contaminated sections of the ship. In the use of water after the ship has been exposed to contamination, special techniques are required to control the contaminating spray resulting from hosing operations. If possible, the hosing of an object should be carried on from the upwind side so that the spray will not drift back on the operators. The most satisfactory operating position is from 15 to 20 feet from the surface. On vertical surfaces, the water should be directed to strike the surface at an angle of 30 to 45 degrees. The complication of a brisk wind partially offset by using a wind-break. For hosing down large contaminated areas, a decontamination rate of approximately 4 square feet of surface area per minute should be used. Special attention must be given to the drainage from these operations to allow direct flow to disposal points over the side.

c. Hosing is not the complete answer to decontamination; scrubbing techniques may have to be used.

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APPENDIX G
DECONTAMINATION PROCEDURES
(Continued)

d. Wooden surfaces, if contaminated, can be decontaminated as outlined below under General Boat Decontamination Procedures.

5. General Boat Decontamination Procedures

a. If the boat exterior, i.e., painted surface, is contaminated from passage through contaminated water, hosing down and scrubbing if necessary should be sufficient to reduce any contamination to well below prescribed tolerances. If boat is water-borne, drainage from hosing down should present no problem. Dispersal of radioactive products in the sea is anticipated to be sufficient to prevent recontamination of other boats. If interior of boat is contaminated, hosing down and pumping out over the side should suffice. However, repeated use of this method can concentrate some contamination in the bilge pump system which is not desirable, and this pump should be especially monitored.

b. Contamination can be introduced into boats by contaminated passengers, radioactive "fallout," or seepage of contaminated water into bilges. It is considered most likely that any major contamination in the boats will come from contamination on passengers and equipment brought on board. Unpainted wood will not be as readily decontaminable as described above. Any contamination should be relatively light. If relatively light and too resistent to normal hosing down, scrubbing and scraping, a coating of shellac, varnish or paint will usually effectively shield out alpha and beta radiation and seal it in until radioactive decay completes the process of removal of any health hazard. It is planned that all boat decontamination will be done in an open sea area where water disposal from low order of contamination and drainage is no problem.

6. General Personnel Decontamination Procedures

a. At the completion of decontamination operations on shipboard, personnel concerned should be monitored on the spot--then shed outer (protective) clothing, gloves, booties, etc., disposing of same into covered containers. Personnel then are monitored and if necessary sent to a personnel decontamination center. (See Appendix I of this Annex, Paragraph 3a.)

b. Personnel upon completion of their duties in a contaminated area will be required to utilize the facilities within a "change house" and, if necessary, those within the decontamination head. They should be organized and operated in such a way that the following is insured:

1) Monitoring of suspected contaminated personnel at "change house" ENTRANCE.

2) Advising each person as to degree of contamination and spots more highly contaminated than others, paying special attention to soles of shoes, hands and hair.

3) Instruction of incoming personnel contaminated clothing should be disposed. This clothing may require laundering or, as a result of decay of radioactive contamination, it may be possible to re-use it after a period of time without laundering.

4) Monitoring of personnel with and without clothing when clothing is contaminated.

5) Collection of dosimeters worn by persons entering decontamination centers.

6) Shower facilities where personnel will scrub thoroughly with particular attention to hair and hands when contaminated.

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APPENDIX G
DECONTAMINATION PROCEDURES
(Continued)

7) Second monitoring after shower and release of personnel if skin count is less than 1 mr/hr (gamma only). Washing should continue as necessary subject to the provisions of Paragraph 3a(1) of Appendix I to this Annex.

7. Disposition of Contaminated Items

Contaminated items which are impossible or impractical to decontaminate may be surveyed or kept in a space, such as a void, where they will not be hazardous to personnel until natural radioactive decay renders them harmless. Advice on disposition of contaminated items may be obtained from CTG 7.3. Contaminated items which will float shall not be thrown overboard except by permission of CTG 7.3.

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APPENDIX G

RADIOLOGICAL SURVEY, AIR DROP AND SAMPLE RETURN PLAN

(Extracts from Appendix III to Annex G, TG 7.3
Operation Plan 1-55)

1. General

a. Radiological/Temperature Survey and Air Drop Missions are independent missions. However, because of time and aircraft availability considerations these missions will be consolidated and conducted by AD-5N aircraft of Carrier Air Support Unit 7.3.2.

b. These missions are to be conducted on D-Day subsequent to H-hour, as contained in air schedules, Appendix I to this annex. Two aircraft will be on station to execute these missions. Each aircraft will have a duplicating mission should the other plane fail to execute its assignment.

2. Control

a. AD-5N and AF-2S aircraft will report to LAZARUS on the TATC (Tactical Air Traffic Control) Net (339.4 MCS) for control. Be prepared to operate on TAD (Tactical Air Direction) Nets as contained in Communications and Electronics Plan, Annex C. TAD #1 - 236.2 MCS, TAD #2 - 349.0 MCS.

3. Radiological/Temperature Survey

a. This mission is to be conducted subsequent to H-Hour and is for the purpose of determining and forecasting the radiological and hydrographic conditions in the test area. Instruments capable of detecting and measuring the radiological conditions (aerial survey and bolometer gear), and two technicians and one observer to observe and interpret these instruments will be placed aboard each survey plane. Survey missions are planned for daylight hours only.

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APPENDIX G
RADIOLOGICAL SURVEY, AIR DROP AND SAMPLE RETURN PLAN
(Continued)

b. Survey aircraft No. 1 and No. 2 will take position 045° upwind on the starboard side of the ZERO BARGE at a distance of 5 miles and an altitude of 1,500 feet (or below the overcast), and be prepared to commence run-in at H+5 minutes or when the radiological situation permits. The time specified for the initial run-in (H+5 min.) may be delayed; however, the initial run-in point and flight pattern for drops will remain constant.

c. The initial run will be approximately parallel to the array towards the SHOT ZONE to a point at which a starboard turn will permit the track to cross the array one thousand (1,000) feet upwind of the SHOT ZONE at 2 minutes after start of run-in. This preliminary survey run will be conducted at an altitude of 1,500 feet until past the SHOT ZONE area at which time altitude will be decreased to 500 feet in preparation for dropping runs. Survey plane No. 1 will be the lead plane throughout drop and survey missions, and survey plane No. 2 will follow at a distance of 2,000 yards. Upon completion of the preliminary survey run, survey planes will execute two (possibly three) runs for the dropping of water sample collectors and radiac instruments.

d. Upon completion of the drop runs, a survey pattern will be initiated. This pattern will be largely determined by the size of the water area to be covered; the larger the area the more detailed a pattern can be flown. Should the area remain small, the pattern will consist of runs across the SHOT ZONE. Pattern determinations will be made on the basis of information received by program directors. In the event that it becomes necessary for survey planes to delay or suspend operations and maintain an orbit about a reference position, this point will be the initial run-in point (subsequent to H-Hour this will be off port bow of the MT MCKINLEY (AGC-7).

APPENDIX G
RADIOLOGICAL SURVEY, AIR DROP AND SAMPLE RETURN PLAN
(Continued)

e. Survey mission on D-Day will be scheduled from H+60 minutes to H+3 hours, and H+4 hours to H+6 hours, or as daylight hours permit. Survey missions subsequent to D-Day will be tentatively planned as a one-plane 2-hour flight in the early morning and a one-plane, 2-hour flight in the later afternoon.

4. Air Drops

a. Survey plane No. 1 will drop five USQ-1 telemeters from an altitude of 500 feet during the first run through the SHOT ZONE. Survey plane No. 2 will drop ten water sample collectors from an altitude of 500 feet during the first run through the SHOT ZONE.

b. During the second run through the SHOT ZONE, Survey Plane No. 1 will drop ten water sample collectors and Survey Plane No. 2 will drop five USQ-1 telemeters.

c. Upon completion of the second run, both survey plane No. 1 and survey plane No. 2 will have two water sample collectors and five radiac USQ-1 instruments remaining. These may be dropped on a third run, either immediately following the second run or when considered necessary by CTG 7.3.

d. It is desired that the first drop be conducted perpendicular to the tow array through the center of the SHOT ZONE and to give a coverage of 50 percent on each side of the ZONE which is estimated to be 1,000 feet in diameter. The second drop will be made parallel to the array through the center of the ZONE with the same coverage desired. Runs parallel to the array will maintain a 200-yard separation from the array units until aft of balloons at which time a turn into the SHOT ZONE may be made.

APPENDIX G
RADIOLOGICAL SURVEY, AIR DROP
AND SAMPLE RETURN PLAN
(Continued)

e. Survey plane No. 1 will indicate IFF mode 1, and survey plane No. 2 will indicate IFF mode 2 throughout the survey and drop mission. Radar tracking will be used on these aircraft to obtain detailed flight path/time information which will be utilized for scientific computations.

f. See Tab A - Maneuvering Plan for Drop and Survey Aircraft.

5. Sample Return

a. AF-2S type aircraft based aboard USS WRIGHT will be utilized to return radioactive samples from the carrier to NAS, North Island. At North Island the samples will then be readied for further shipment and transferred to Military Air Transport Service (MATS) aircraft for delivery to interested laboratories. The necessity for early sample delivery requires efficient and accurate coordination on the part of the aircraft units concerned.

b. Sample return missions will commence as soon as possible on D+1 Day subsequent to recovery and processing of water samples. Estimated requirements indicate that two planes will return to North Island on D+1 Day and two planes will return on D+2 Day. Subsequent return missions may be scheduled if necessary. No scheduled night carrier operations are contemplated, however, night landings at NAS North Island are to be expected.

c. In the event NAS North Island goes below safe weather minimums for carrier aircraft, sample return aircraft can expect to be sent to NAS Miramar as alternative number one or NAS El Centro as alternate number two. AF and AD type pilots are to be advised of this possibility and be sufficiently prepared for this situation. MATS aircraft awaiting samples for delivery to the interior will be aware of weather complications and will be prepared to effect rendezvous with

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APPENDIX G
RADIOLOGICAL SURVEY, AIR DROP AND SAMPLE RETURN PLAN
(Continued)

carrier sample delivery planes at alternate base one or two as specified. CTU 7.3.5 (VP-2) will coordinate this sample transfer rendezvous as necessary.

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES (Extract from Reference 4)
Brochure of Course Material,
Course I (Four Weeks)

DAY	TITLE	HOURS	DESCRIPTION
1	Registration and Administration	1	Discussion of rules and regulations; clearance check; course materials are issued; student aid is given to those who need it
1	Introduction to the Effects of Nuclear Weapons	1	Glossary of terms introduced; various types of bursts are discussed as well as an overview of effects; orientation is directed to the student's possible participation in a field operation
1	Blast Effects of Nuclear Radiation	3	This class provides an overview of nuclear blasts and the blast-effect-according to the type of burst (such as damage to structures, ships, materials); problems of scaling and damage criteria are considered
1	Review of Basic Math	1	The fundamentals of basic mathematics, requisite to the course are reviewed
2	Blast Effects; and Damage Criteria	2	The problems pertaining to blast scaling and damage criteria are discussed and solutions are evolved by actual calculations
2	Thermal Radiation Effects of Nuclear Explosions; "Fireball Phenomena"	2	The class discusses the effects of heat on ships, structures, and material; a comparison is made between thermal and total hazard of nuclear detonation
2	An Introduction to Nuclear Radiation	1	This film-lecture discusses the basic structure of the atom and its relation to nuclear radiation
2	Review of Basic Math	1	Second session reviewing the fundamentals of basic mathematics
3	Examination, Discussion and Critique	1	An examination on blast and thermal effects, followed by a discussion of the exam material

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course I (Four Weeks) (Continued)

DAY	TITLE	HOURS	DESCRIPTION
3	Introductionn to Nuclear Radiation, II	1	The 2nd introductory lecture on the elementary structure of the atom and on nuclear radiation so that the student has a general idea of nuclear weapons and radiac instruments and a basic understanding of the need for radiological safety
3	Nuclear Radiation Effects I and II	2	The types and physical characteristics of nuclear radiations are discussed relative to their importance to types of nuclear detonations
3	Nuclear Radiation, Scaling of Effects, I and II	2	The problems involved in scaling and shielding of nuclear radiation are presented and solution are evolved by calculation
3	Fission Products and their Decay	1	The problems concerning the decay of fission products are presented as well as a discussion on fission-product monitoring
4	Detection of Radiation	1	Students are introduced to the use of radiacs and are shown the application of radiation characteristics to such detecting radiation detection methods as ionization and scintillation
4	Basic Instruments		The basic radiac instruments and general operating principles are presented along with basic instrument theory and simple concepts of electronic detection circuits
4	Dosage Devices	1	The student is shown film and chamber dosimeters used for recording radiation doses, and how to use and care for them
4	Introduction to Lab Exercises "Introduction to Radiac Instruments"	1	Students are shown laboratory procedures; a film on radiac instruments is shown

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course I (Four Weeks) (Continued)

DAY	TITLE	HOURS	DESCRIPTION
4	Individual Naval Radiac Instruments; Calibration of Instruments	1	A discussion and demonstration of the operation calibration and formulas, maintenance and limitations of the radiation measuring instruments used by the Navy for routine and/or special operations (AN/PDR-TIB, AN/PDR-27 C, and AN/PDR-18A)
4	Calibration of an Ion Chamber	2	Students learn the use of an ionization type radiac by taking readings with and calibrating an AN/PDR-TIB. Students are shown how to determine operational characteristics through the means of calibration curves
5	Examination, Discussion and Critique	1	The exam includes material studied on nuclear radiation effects such as initial gamma scaling, attenuation, and shielding, followed by a critique of the exam
5	Fission Product Decay and Dosage	1	A discussion on the problems involved in the decay of fission products, and on the needs and possible ways of interpreting estimated dosage is held
5	Problems in Fission Product Decay and Dosage	1	The student is asked to solve fission-product decay and dosage problems using available information
5	Measurements and Evaluation of Radiological Hazards, I and II "Radiological Survey'	2	A discussion of the need for radiological survey, types of survey, marking of areas and equipment, control operations, as well techniques used in making an evaluation of a radiological hazard is held, highlighted by a film

COPY

APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material,
Course I (Four Weeks)
(Continued)

DAY	TITLE	HOURS	DESCRIPTION
5	Area Monitoring Survey	2	Students practice the procedures to be used in operational conditions, as a simulated survey takes place onboard a model vessel; survey readings are taken using radiacs, and reports are then sent to control centers for evaluation
6	Exam, Discussion and Critique	1	This exam covers material on fission products, decay and dosage
6	Problems of Dosage Calculation, Decay, and Stay Time Re: FP Contamination	3	Dosage and stay-time problems for residual contamination from nuclear weapons are calculated by graphical means
6	Contamination		The sources, implications and hazards of radiological contamination, as well as definition of terms, are covered
6	Shielding		This laboratory practical exercise deals with the materials used for shielding radiation and the factors in shielding problems
7	Decontamination I and II: "Industrial Decontamination of Ships"	2	This film-lecture discusses the fundamental principles of decontaminating radioactive surfaces; procedures used in removal; compares the efficiency of various techniques for routine and emergency decontamination; and operational and final clearances
7	Medical Aspects of Nuclear Weapons: Radiological Hazards "Effects of Radiation on the Body"	2	Radiological hazards from a medical standpoint are presented as well as the biological effects of ionization, radiation symptoms and sickness, followed by a training film
7	Thumb Rules	2	Practical rules to apply while working with radioactivity are discussed

COPY

APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course I (Four Weeks) (Continued)

DAY	TITLE	HOURS	DESCRIPTION
7	Thumb Rule Applications	1	A group discussion on how to apply "rules of thumb" to radiological situations. Emphasis is placed on the constant application of radiological safety principles for personnel protection
8	Exam, Discussion and Critique	1	This exam covers material presented the previous two class days
8	Monitoring Survey, Afloat	3	The student, using radiac instruments, takes part in a field exercise aboard the USS BUTTERNUT, a full-size model of a naval vessel. In this exercise a simulated contaminating event is staged and the monitor evaluates hazards, using monitoring procedures, and recommends Rad-Safe procedures to higher authority based on survey
8	Monitoring Survey Ashore	3	This field exercise stages a simulated contaminating event on land. Using radiac equipment, the monitor identifies and marks contaminated areas; evaluates radiological hazards to personnel; and forms monitoring reports and isointensity line charts
8	Interrelation of Effects (Classified Film)	1	This discussion correlates the interrelation of thermal, blast, and radiation effects as they apply to different types of nuclear detonations
9	Radiological Recovery I, II, and III	3	The aspects of radiological recovery, following a contaminating event, are covered, as well as the most effective measures necessary to return a land area or ship to use. The "Radiological Recovery Manual" is referenced

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material,
Course I (Four Weeks)
(Continued)

DAY	TITLE	HOURS	DESCRIPTION
9	San Francisco Problem	3	In this practical exercise. the student is asked to estimate blast, thermal, and nuclear radiation damages and dangers produced by two nuclear detonations in San Francisco. The student plots the extent of radioactive contamination, gamma fluxes, and personnel doses, using available information
10	Examination, Discussion and Critique	1	This examination includes all material covered in the previous two days of the course
10	The Harbor Attack	1	Classified
10	Thermonuclear Reactions	1	Classified
10	Individual Survival in a Nuclear Attack "Survival Under Atomic Attack"	1	This film-lecture demonstrates methods of survival and freedom from hazard during a nuclear weapon attack
10	Field Operations (Operation Ivy)	1	A classified film on a recent Armed Forces field operation at the site of a nuclear detonation is shown to further orient the student to field operations.
10	Review and Discussion		A review and discussion of the first two weeks' material; all important points are highlighted and any necessary additional information is added
11	Meteorology: "Weather In Operation Sandstone"	1	Meteorological data showing the effect of weather on field conditions and its consequent effect on hazard magnitudes are discussed

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course I (Four Weeks) (Continued)

DAY	TITLE	HOURS	DESCRIPTION
11	The Shio Contamination Complex: Fallout and Fallout Problems	1	This class examines the nature of radioactive fallout in detail; chemical and physical factors influencing the nature of resultant contamination on board naval vessels are discussed; the variety and magnitude of contamination problems as a result of fallout are enumerated, in addition to operational and industrial implications
11	"Operation Ivy" "Operation Doorstep"		Visual aids serve the monitor in his further orientation to the conditions of operations in the field. Films portraying security, hazards, mission, magnitudes, and radiological safety are shown
11	Evaluation, Delineation, and Control of Radioactive Contamination		This discussion augments the material presented during the first two weeks and includes the principles of hazard detection, evaluation, and control of radioactive contaminated areas; step-by-step-procedures for setting up and/or recognizing hazard controls; warning tags and signs; MPE and stay-time calculations
11	Operation of a Geiger Counter (Count-rate meter); Geometry Factor in Counting	3	In the laboratory, the student learns how to operate a count-rate meter and to take measurements with it; the applications of the count-rate meter for wipe sampling analysis, low-level contamination,survey, and continuous background monitoring in the field are explained; a laboratory exercise stressing the importance of the geometry factor in taking radiation measurements is held

COPY

APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course I (Four Weeks) (Continued)

DAY	TITLE	HOURS	DESCRIPTION
12	Change House Exercise; Personnel Monitoring Instrumentation; Personnel Decontamination Techniques	4	A change house exercise provides training in the use of protective clothing, dress-out and undress personnel procedures, principles of personnel decontamination, and the instrumentation used for personnel monitoring are presented
12	Radiological Safety Facilities	3	A tour, showing the following types of facilities for radiological safety is taken at NRDL; isotope storage, shielding, liquid waste disposal tanks and equipment, decontamination facilities, radiation sources, safety controls and interlocks, hand and foot counters, emergency decontamination showers, a typical change house, and waste disposal storage and handling
13	Radioactive Waste Disposal Problems for Field Operations	1	The problems associated with disposal of radioactive wastes, particularly for field operations, are considered; the basis of the decision for decontamination, storage, or disposal as waste is presented; the problems of handling, packaging, storage, movement, records, legal factors, monitoring, and proper labeling are also considered
13	Area Survey and Monitoring Techniques; Aerial Survey	1	Previous material on the various techniques for area survey, as conditioned by types of radiation being measured and types of surface or material, is reviewed; the techniques for gamma survey, using low-flying aircraft, are also presented; Cutie Pie and side-window G-M tube instruments are discussed

COPY

APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course I (Four Weeks) (Continued)

DAY	TITLE	HOURS	DESCRIPTION
13	Concepts of Radiation Dosimetry	1	The basic concepts used in measuring an integrated dose of radiation received by personnel are introduced; use of film badges, use and reading of dosimeters, and safe handling of film supplies are demonstrated
13	Air and Water Sampling, and Analysis	1	The techniques of obtaining and analyzing samples of air and water for the determination of contamination are evolved; a demonstration of counting methods is made using an electronic scaler; analysis is then made by calculation of the results of counting
13	Recording and Documentation of Radiation Measurements	1	The methods for recording the various types of radiation measurements are covered as well as forms used, transmittal of records and information, legal records, and BuMed requirements
13	Safe Handling of Radioactive Material	1	By applying the principles of radiological safety, the student learns standard techniques and work practices for the handling of radioactive material, including use of sources, contaminated objects, and radioactive materials in the laboratory; remote handling tools and the factors of time and distance are also discussed in relation to safe handling
14	"Industrial Radiological Decontamination of Ships, Contaminated Ships Handling"; Decontamination of Radioactive Surfaces	1	The material presented during the first two weeks is now augmented by further material on decontamination; this section refers specifically to ships and includes removal techniques, evaluation, tolerances, and clearances as applied to field operations

COPY

APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course I (Four Weeks) (Continued)

DAY	TITLE	HOURS	DESCRIPTION
14	Techniques for Sample Counting, Air Sampling Techniques	3	The techniques and instruments used for counting radioactive samples, preparation of samples for counting, scaler operation, use of standards, and background problems are explained and demonstrated; an air sample is taken by the student, and the sample is then counted with a scaler
14	Decontamination of Surfaces, Wipe Sampling Techniques	3	Students are given a demonstration showing decontamination techniques on such commonly used shipboard materials as paint, clean and rusty steel, wood, and glass; the student engages in a training exercise in the techniques of sampling for the presence of removable radioactive contamination by wipe sampling; the progress of a decontamination procedure is checked by the use of wipe samples to determine the extent of removal
15	Study, Review and Critique of Course Material	2	The class instructor will hold a review and discussion of highlights in the material covered during the course's third week; a film detailing a field operation will be shown
15	Shipboard Training Manual	2	The group will study and discuss the "Shipboard Training Manual," and suggestions will be made for its application and use in carrying over to other personnel the principles of radiological safety in the organizations where they are regularly assigned
15	Monitoring Survey (localized contamination)	2	A training exercise is held using radiacs, determining the location and extent of localized contamination levels; the monitoring and marking of areas and the evaluation of personnel hazards are stressed

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course I (Four Weeks) (Continued)

DAY	TITLE	HOURS	DESCRIPTION
15	Survey Evaluation	1	Evaluation of the above survey is made by the group by discussion and critique; the monitoring reports are evaluated, and conclusions for action or recommendation to others are made; assembly and charting of data are discussed
16	Examination	1	This exam will cover basic principles in the course material covered during third week
16	Discussion and Critique	3	The exam given in the previous period will be discussed by the group, and a critique will be held on the material
16	Absorption of Beta Radiation; Absorption of Gamma Radiation	2	Two laboratory exercises, showing the student the relative range and penetrating power of beta and gamma radiations, are given; data are collected and graphs of half-value layers are made
16	"Radiological Survey"; "Radioactive Contamination"	1	Further visual aids on the subjects of monitoring and contamination are given, along with appropriate commentary by the instructor
17	Monitoring Survey		Further training in the use of radiacs and in survey techniques is given; particular attention is paid to correction of weak points discovered in previous exercises; isointensity lines, dosage problems, stay-time calculations, and thumb rules are considered
17	Discussion and Critique; 'Practice of Rad-Safety"	3	The monitoring survey is evaluated by the group, as was done on day 15 for a previous survey; discussion of any further weak points takes place; a film on principles is shown and discussed by the group

COPY

APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course I (Four Weeks) (Continued)

DAY	TITLE	HOURS	DESCRIPTION
18	Monitoring on USS BUTTERNUT	4	A second session on monitorina is held aboard the BUTTERNUT; further training is held on shipboard survey
18	Survey Evaluation	2	An evaluation of the above survey is made by group discussion and critique
18	"Atomic Bomb Test, Bikini" "Principles of Radiological Safety, Part V"	1	Supplementary visual aids are presented by the instructor on underwater nuclear weapon detonation and on radiological safety principles, followed by comment
19	Scattering of Beta Radiation		A laboratory exercise demonstrates the characteristics of beta scattering and its effect on beta-radiation measurements
19	Instrument Test; "Trouble Shooting"		The common causes of instrument failure are investigated, and corrective measures are given; symptoms identifying possible troubles are listed, and simple adjustments that may be made in the field to keep radiacs operating are presented
19	Monitoring of Equipment and Personnel	3	A practical exercise demonstrates the instruments and techniques used for monitoring equipment and personnel, followed by a discussion and critique
20	Final Examination	1	This exam will cover all material presented in the course
20	Summary of Training Course	1	The course will be summarized by the Training Officer
20	Orientation (on Operation X)	1	Confidential

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course I (Four Weeks)
(Continued)

DAY	TITLE	HOURS	DESCRIPTION
20	Assignment to Project Duties	1	Assignment to project duties is made by the field-operation Rad-Safe officer
20	Return of Course Materials; Student Aid; Graduation	1	All materials loaned and signed for by students are returned; graduation session is held; administrative matters on check-out are handled
20	Check-out		

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course II (Three and one-half days)

DAY	TITLE	HOURS	DESCRIPTION
1	Registration and Administration	1	Class roster is assembled; school rules and regulations are discussed, security of classified information is discussed; administrative matters pertaining to course enrollment are handled; student aid is given those in need of it
1	Introduction		The scope of the sources is discussed by the Training Officer; orientation is directed to the student's possible participation in a field operation; an introduction to the principles of radiological safety is provided
1	"Survival Under Atomic Attack"; "Effects of Atomic Bomb Explosions"		Films and commentary outline the most effective measures to be taken by personnel in the event of a nuclear detonation; blast, heat, and radiation effects are considered
1	Nomenclature of the Radiation Sciences and of Bomb Phenomenology		Terms used in dealing with radioactivity are defined; definitions of bomb "language" and field-operation terminology are given; this will serve as an introduction to the presentation, in the next lecture, of the basic physics of nuclear structure
1	The Characteristics of Radiation, Ionization and Contamination	1	Students are presented with a review of the basic physics of the nuclear structure; discussion is held on the fundamental concepts of radiation, interaction of radiation with matter, the meaning of radioactive contamination, and definitions of isotopes and half life and decay; this is to provide the student with enough theory and physics terminology to give him a general concept of how nuclear weapons and radiac instruments operate, and a basic understanding of the importance of radiological safety

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material,
Course II (Three and one-half days)
(Continued)

DAY	TITLE	HOURS	DESCRIPTION
1	"Self-Preservation under Atomic Attack, Pt. 1"; "Medical Aspects of Nuclear Radiation"	1	Effective countermeasures used to reduce the possibility of biological damage, the effects of radiation on personnel, and protective measures are discussed
1	Hazards Associated with Nuclear Weapons Associated Field Operations	1	Blast and thermal hazards are treated briefly; radiation hazards and and biological effects are stressed; introduction to the types and extent of destruction associated with nuclear blast will dismiss any misconceptions concerning the unique type of energy we are dealing with during field operations
2	"Radiac Instruments" (film); Introduction to the Use of Radiation Measurement Instruments and Demonstration (lecture)	1	Use of radiac instruments for monitoring is presented along with enough basic instrument theory to provide the student with an understanding of the mechanics of operation followed by a demonstration of all radiacs shown in the film and referred to in the lecture
2	Why Efforts are Expended for Radiological Safety (lecture); "Radiological Safety (Operation Crossroads)" (film)		The reasons for expending efforts for Rad-Safe are given, and the basic principles of Rad-Safe are introduced; Task Group safety and effectiveness are stressed; a film showing Rad-Safe measures on a field operation is presented, along with commentary on important points
2	Use of Radiacs for Field Work		This includes actual participation in an exercise introducing radiac instruments; the operation, care, and use of portable radiacs, ion chambers, G-M counters, scintillation counters, and count-rate meters used for field work are demonstrated and discussed; their applications for area survey, equipment survey, and personnel monitoring are demonstrated

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course II (Three and one-half days) (Continued)

DAY	TITLE	HOURS	DESCRIPTION
2	Radiation Exposure Tolerance Levels for Field Operations, MPE's and MPC's	1	The basic concepts of maximum permissible exposures and concentrations are given, as well as reasons for setting them at certain levels for routine and special use; discussion is held on total dose and dose rates allowed; BuMed requirements and task force needs are integrated; the uses of dosimeters and sampling equipment for dose determinations received by personnel are mentioned
2	Safe Handling of Radioactive Materials	1	The principles of radiological safety are further amplified here giving consideration to methods of handling (both removable activity and sealed sources); shielding, distance, and stay-time factors; handling of tools and equipment; relative hazards of isotopes and radiations; warning tags and safeguards; shipping procedures and their rules and regulations
2	Evaluation, Control and Delineation of Radioactive Contamination		Consideration is given to the principles of hazard detection, evaluation, and control and a correlation is drawn with the principles of radiological safety previously discussed; step-by-step procedures for setting up and/or recognizing hazard controls are also discussed; the uses of warning tags and signs are given, and representative samples used by the Navy and the AEC are displayed; MPE and safe stay-time calculations are given and discussed

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material,
Course II (Three and one-half days)
(Continued)

DAY	TITLE	HOURS	DESCRIPTION
2	Introduction to the Principles of Radiation Dosimetry; BuMed Requirements, Task Group Needs, Personnel Exposure Records	1	The student is introduced to the basic concepts of radiation dosimetry including pocket dosimeters, film dosimeters, instruments used to charge and read pocket dosimeters, and densitometers; using his knowledge of basic physics of radiation, he begins to understand how each one operates; the requirements of BuMed for radiation exposure for various types of operations are given, integrating Task Group needs with these requirements; the importance of accurate personnel exposure records (and how they are made) is stressed
3	Biological Effects of Radiation	1	The student learns of the medical aspects attendant to nuclear detonations and the specific types of radiation; consideration is given to the effect of radiation on the human body, the dose that will cause death, sickness, or have no effect at all; RBE of radiations; tissue ionization; radiosensitivity; total dose vs. time received; external and internal effects; medical symptoms and treatment; biochemical reactions; maximum permissible dose (basis for); fission-product effects
3	Personnel Monitoring and Instrumentation and Field Exercise	3	The principles of monitoring the body and clothing for the presence of radioactive contamination are discussed, as well as the instruments and use of protective clothing; the student then participates in an actual change house procedure, performing dress-out and undress, personnel monitoring, and the standard washing and skin decontamination procedure; the principles of personnel decontamination are demonstrated

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material,
Course II (Three and one-half days)
(Continued)

DAY	TITLE	HOURS	DESCRIPTION
3	"Operation Ivy"; Operation Doorstep"	1	Films of recent field operations are shown to orient the student to field conditions and his possible participation in Rad-Safe responsibilities
	Discussion of BuMed Radiological Safety Regulations	1	Once the student has knowledge of the basic radiological safety principles, he is ready to discuss his understanding of how they may be applied during operations involving the use of radioactive materials; a perusal is made of pertinent parts of NavMed P-1325, the Radiological Safety Regulations for the U.S. Navy; a health physicist will lead an informal group discussion to interpret application of Naval regulations as they apply to the use of radioactive materials in relation to anticipated operational functions; distinction between routine and special operations, as well as attendant differences in routines, values, etc., will be stressed
3	Interaction Between the Scientific Group and the Rad-Safe Group of Operation X	1	Orientation for participation in a possible field operation from the viewpoint of interaction and cooperation between the Scientific Group and the Rad-Safe Group of Operation X is presented; ways to attain this objective are suggested and discussed; the parallel philosophies of accomplishment of mission and consistent good practice of radiological safety are stressed

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course II (Three and one-half days)
(Continued)

DAY	TITLE	HOURS	DESCRIPTION
4	Purpose and Use of the Project 0.17 Operational Manual	1	The purpose and use of the manual by project personnel will be discussed giving special consideration to the possible ways in which this document will help the Scientific Group accomplish their mission, and at the same time, effect the maximum degree of radiological safety; presentation will be made of Rad-Safe operating basis and organization, the role of Rad-Safe group in a Task Group organization, and its liaison with other Task Group elements
4	Review and Discussion of Course Work		A recapitulation of all course work is held; the highlights of course material will be reviewed along with any additional information suggested by the students and/or instructors; this is the time to bring up and iron out any weak points of information on any part of the course
4	Summary of Course		A summary of the indoctrination course will be given by the Rad-Safe Training Officer; all important points will be emphasized; the principles of radiological safety and their practical application to the successful accomplishment of a mission involving contaminating events, will be stressed

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course III (Five Days)

DAY	TITLE	HOURS	DESCRIPTION
1	Resistration and Administration	1	Class roster is assembled: rules and regulations of the school'are discussed; security of classified information is discussed; administrative matters pertaining to course enrollment are handled; student aid is given to those who need it
1	Orientation (on Operation X)		The scope of the course is discussed by the Training Officer; orientation is directed to the student's possible participation in a field operation; an introduction to the principles of radiological safety is given
1	Introduction to the Structure of Matter; "Basic Physics of an Atomic Bomb"		The basic structure of atoms is introduced; the parts or building blocks of atoms are presented, and the groundwork for an understanding of radiation, weapons, and instruments is laid down
1	Comparison of HE and Nuclear Explosions	2	This class compares ordinary HE weapons with nuclear weapons; considerable time is devoted to the various types of bursts and their implications; the session is concluded with a glossary of terms
1	Nuclear Radiation and Radiation Units, Ionization	1	The fundamentals of nuclear radiation and its units as well as a discussion of ionization are presented; an introduction to the meaning of radioactivity is given

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course III (Five Days) (Continued)

DAY	TITLE	HOURS	DESCRIPTION
1	Dosimeters	1	The devices used to measure radiation dose are presented; a brief explanation is given of their use and procedures for their intelligent care are demonstrated
2	Medical Aspects of Nuclear Weapons; "Medical Effects of Atomic Bomb"; Medical Aspects of Nuclear Radiation"	3	Lectures and films on the medical aspects of nuclear weapons are presented in layman's terms; the effects of radiation on personnel are given; material is divided into the classical parts of blast, thermal, and nuclear radiation; the first two are treated briefly and coordinated with HE weapons and the various types of nuclear bursts; emphasis is placed upon effects of radiation on the body considered from both the internal and external aspects; technical terms are used sparingly and explained thoroughly
2	Introduction to Radiac Instruments, "An Introduction to Radiation Detection Instruments"	2	The need for radiac instruments and the methods for using them are discussed; principles of the various types of radiac field instruments are presented, followed by a film on instruments
2	Instrument Trouble Shooting	1	The common causes of instrument failure and corrective measures, as well as symptoms that identify possible troubles, are listed; simple adjustments that may be made in the field to keep radiacs operating are presented
2	Calibration of Instruments	2	Radiac instruments are handled by the student for the first time; using radioactive sources, instruments are used to take readings and are calibrated against known sources

APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course III (Five Days) (Continued)

DAY	TITLE	HOURS	DESCRIPTION
3	Personnel Contamination and Decontamination	4	Now that the student has a basic knowledge of radioactivity and contamination, he receives a practical exercise in the procedures involving the contamination and decontamination of personnel; change house procedure is discussed, the techniques of personnel decontamination are presented and standard rules are given for this situation; protective clothing used in contaminated areas is discussed and demonstrated; the importance of personnel monitoring is stressed
3	Area Survey		By actual participation in an exercise using radiac instruments, an area survey is conducted, and practical use is made of areas and objects; G-M and ionization type radiacs are used and discussed (also, their care and field application are discussed)
4	Measurement and Evaluation of Radiological Hazards		Using the student's knowledge of radiological safety as background, a discussion is held on techniques for measurement and evaluation of radiological hazards; this includes the application of side-window G-M radiacs, Cutie Pies, air samplers, and wipe sampling; principles of radiological safety and application, concepts of MPE, and the implications or radioactive fallout are presented
4	Area Contamination, Decontamination	3	The events following a contaminating event and the application of the principles of radiological safety by personnel are presented; further discussion on Rad-Safe applications, MPE, and fallout is held; basic measures for the effective initial decontamination of an area are described

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course III (Five Days) (Continued)

DAY	TITLE	HOURS	DESCRIPTION
4	Shipboard Monitoring (USS BUTTERNUT)	4	Students experience actual shipboard monitoring conditions by participating in a 4-hour exercise which provides training in the shipboard use of instruments; a discussion is held on the evaluation of the hazard data collected
5	Self-protection; "Self-preservation in an Atomic Bomb Attack"		Lecture, film, and commentary outline the most effective measures to be taken by personnel in the event of a nuclear blast; the principles and applications of good Rad-Safe practices are stressed, and emphasis is placed on the fact that these measures are effective
5	Self-protection, Mask Drill and Exercise	3	A practical exercise takes students through a change station and into a gas chamber with use of a protective mask
5	Personnel Monitoring	1	The principles of monitoring the body for the presence of radioactive contamination are discussed, as well as the use of protective clothing and instruments
5	Final Examination	1	A final examination, covering all previous course work, is given
5	Critique	1	A group discussion and critique on the examination and the entire course led by the Training Officer is held; an opportunity is given for a recapitulation of all course work; the highlights of course information will be reviewed, and any additional information needed will be added; this is the time to bring up and iron out any weak points of information on any part of the course

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course III (Five Days)
(Continued)

DAY	TITLE	HOURS	DESCRIPTION
5	Turn in Equipment on Loan; Graduation; Check-out	1	All materials loaned and signed for by students are returned; graduation session is held; administrative matters on check-out are handled

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material, Course III-A (Two Days)

DAY	TITLE	DESCRIPTION
1	Registration and Administration	Class roster is assembled and administrative matters pertaining to mechanics of the course are handled
1	Orientation	The scope of the course is outlined by the Training Officer; orientation will be directed to the student's possible participation in a field operation; introduction to the principles of radiological safety is given
1	Comparison of HE and Atomic Explosions	HE weapons are compared to nuclear weapons; considerable time is devoted to the various types of bursts and their implications; a glossary of terms is included
1	Nuclear Radiation and Radiation Units, Ionization, Movie, MA-7004	The fundamentals of nuclear radiation and its units and a discussion of ionization are presented; students are provided with an introduction to radioactivity
1	Introduction of Radiac Instruments; Movie, Introduction to Radiation Detection Instruments, MA-7630 A	The need for instruments is demonstrated as well as the methods of using them; principles of the various types of radiac field instruments are touched upon such as operational use, calibrations, and simple care; a film on instruments is included with the lecture material; various types of field instruments will be made available for the student to use

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APPENDIX H

DESCRIPTION OF RAD-SAFE COURSES

Brochure of Course Materials,

Course III-A (Two Days)

(Continued)

DAY	TITLE	DESCRIPTION
1	Measurement and Evaluation of Radiation Hazards	A discussion is held on techniques for measurement and evaluation 'of radiological hazards including the application of side-window G-M radiacs, Cutie Pies, air samplers, and wipe samplers; principles of radiological safety and application, concepts of MPE, and the implications of radioactive fallout are presented; simple instructions and demonstrations of instrument calibrations are also included
1	Dosimetry	The devices used to measure radiation dose are presented; a brief explanation is given on how to use and take care of them; the various types are displayed and demonstrated
1	Area Survey	By actual participation in an exercise using radiac instruments, an area survey is conducted and practical use is made of areas and objects; G-M and ionization type radiacs are used and discussed (also, their care and field application are presented)
2	Medical Aspects of Nuclear Weapons	Lectures and a film on the medical aspects of nuclear weapons are presented in layman's terms; the effects of radiation on personnel are given; material is divided into the classical parts of blast, thermal, and nuclear radiation; the first two are treated briefly and coordinated with the HE weapons and the various types of nuclear bursts; amplification of information on radiological safety application, MPE, and fallout is made; emphasis is placed upon effects of radiation on the body, considered from both the internal and external aspects; technical terms are used sparingly and explained thoroughly

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APPENDIX H
DESCRIPTION OF RAD-SAFE COURSES
Brochure of Course Material,
Course III-A (Two Days)
(Continued)

DAY	TITLE	HOURS	DESCRIPTION
2	Personnel Contamination and Decontamination		Using his basic knowledge of radioactivity and contamination, the student receives a practical exercise in the procedures involving contamination and decontamination of personnel; change house procedures are discussed; the techniques of personnel decontamination are presented, and standard rules are given; the protective clothing used in contaminated areas and the importance of personnel monitoring are stressed
2	Area Contamination and Decontamination		The pattern of events following a contaminating event and the application of the principles of radiological safety are presented; basic measures for the effective initial decontamination of an area are discussed; a practical exercise involving participation of the students will be conducted
2	Self-protection, film NM-9116		Additional information regarding change station procedures, fundamental principles of radiological safety as applied to actions in the field, and basic "do's and don't's" are outlined
2	Critique		The Training Officer leads a discussion and critique on the entire course; an opportunity is given for a recapitulation of all course work; the highlights of course information will be reviewed, this is the time to bring up and iron out any weak points of information on any part of the course

APPENDIX I
OPERATIONS PROJECTS

TECHNICAL PROJECTS.

PROGRAM I - FREE-FIELD MEASUREMENTS.

Project 1.1 Predictions of Underwater Explosion Phenomena (Reference 19).

The objective of Project 1.1, fielded by the U.S. Naval Ordnance Laboratory, was to determine the principal underwater explosion phenomena from the detonation of an atomic device, at a depth of 2000 feet in deep (15,000-foot) water, in order to:

o Increase the knowledge of such phenomena

o Enable the proper location of the targets and instrumentation during the operation

o Further develop methods for predicting underwater explosion phenomena for other yields and firing geometries.

This was a survey of various calculations that gave predictions that were used to help determine the experimental configuration. Comparisons of the predictions were made to the actual measurements.

Project 12 Underwater Free-Field Pressures to Just Beyond Target Locations (Reference 20).

The U.S. Naval Ordnance Laboratory fielded Project 1.2. The purpose of this project was to measure underwater pressures in the region from a range of approximately 1500 feet to 12,000 feet from surface zero. In addition, measurements were to be made from depths of 25 to 2000 feet, including the region where large, scaled models of submarines were located as targets.

Recovery commenced on the night of D-day with the withdrawal of the two NOL gage strings on the YFNB-13 (approximately 8000 feet from surface zero). The remaining YFNB strings were recovered during the morning of D + 1. It was not until the afternoon of D + 1 that recovery work was begun on the equipment which had been attached to the towline. The search was done by two helicopter surveys, with two helicopters for each survey, and by the USS TAWASA (ATF-92). By evening, the latter had recovered the O-1 buoy, both spar gage lines and two of the ball-crusher-gage buoys from which the gate strings had been lost. The 0-2 buoy was recovered the next day, and two of the ball-crusher-gage lines and buoys were never seen.

Project 1.2.1 Free-Field Pressures, Station Zero (Reference 21).

The objective of this project by the Naval Research Laboratory was to measure the characteristics of the shock wave in water from close-in to 2,500 feet. Figure I-1 shows the physical arrangement of the weapon array which concerns Project 1.2.1. At station zero, 30 gages were assembled in a bundle as shown in Figure I-2.

Project 1.3 Underwater Free-Field Pressure Measurements (Reference 22).

The Navy Electronics Laboratory fielded Project 1.3. The objective of this project was to determine free-field pressures as a function of time, depth, and range at distances greater than 5000 feet from a deep underwater atomic bomb burst, and to study the influence of refraction conditions and surface and bottom reflections on these pressures. Free-field pressure measurements were made from the barges YFNB-12, YFNB-13, YFNB-29 and the LCM at horizontal ranges of 5505, 7943, 10,923 and 10,923 ft, respectively. The pressure-time gages were located at a depth of 20, 40, 60, 100, 150, 250, 400, 600, 800, and 1000 feet.

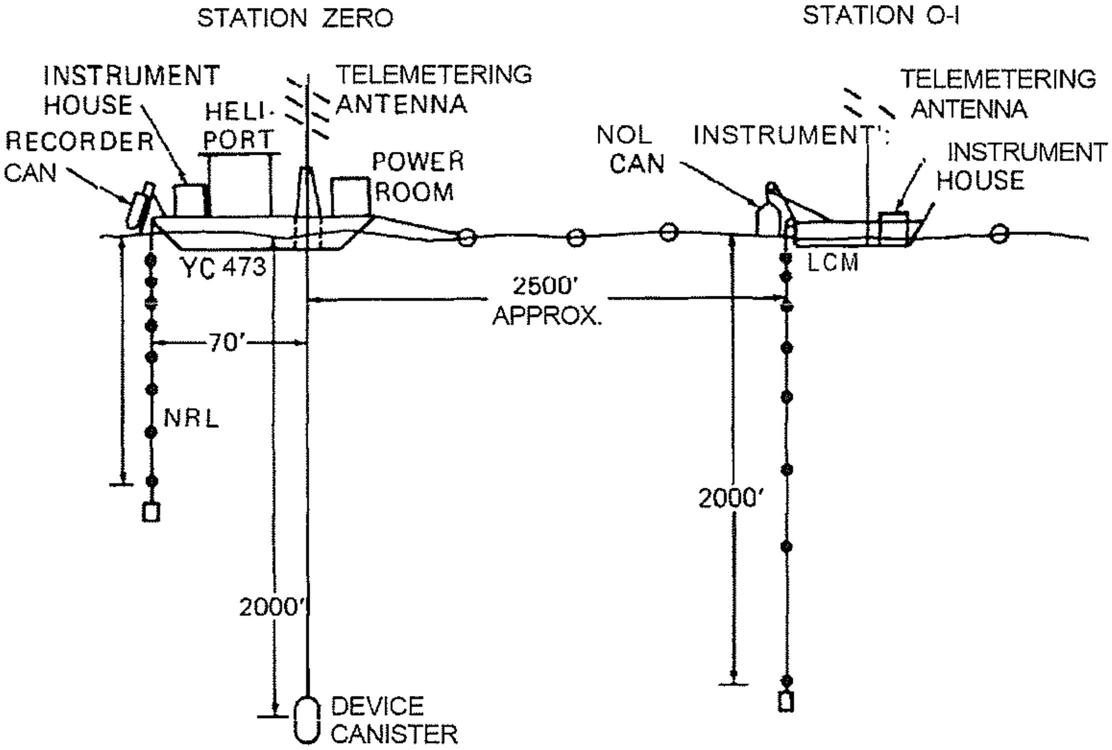


Figure I-1. Arrangement of weapon array.

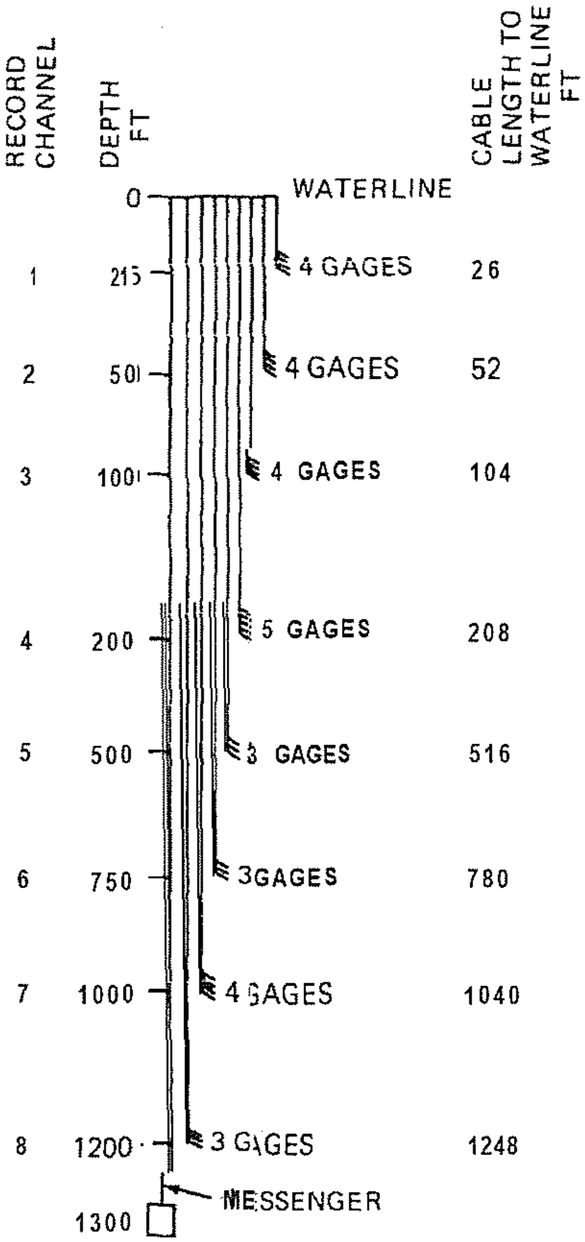


Figure I-2. Station zero cable bundle.

Project 1.4 Bubble Phenomena (Reference 23).

The first objective of this project fielded by the U.S. Naval Ordnance Laboratory was to measure the energy of the radial flow of water associated with the explosion bubble by a determination of the maximum water displacement and to measure the period and maximum radius of the bubble. The second objective was to determine the degree of similarity between the bubble effects from a high explosive and an atomic explosion.

At the YFNB-12, a fouled winch could not be cleared due to bad weather. At YFNB-13 rough seas caused damage which prohibited the lowering of the instruments. No useful data were obtained.

Project 1.5 Photographic Measurements of Surface Phenomena (Reference 24).

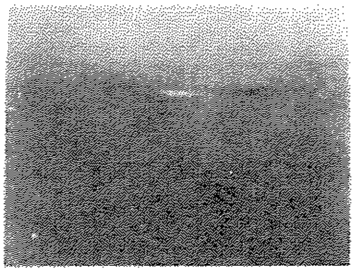
This U.S. Naval Ordnance Laboratory project was established to determine the characteristics of the visible surface phenomena of a deep underwater nuclear burst.

By means of timed photography, the slicks, spray domes, plumes, base surge, and residual cloud were studied. See Figures I-3 and I-4.

Project 1.6 Underwater Optical Measurements (Reference 25).

The Office of Naval Research measured the time duration and magnitude of the underwater light pulse in order to:

- Document the history of the underwater fireball
- Attempt to utilize the data obtained for calculating the yield of the weapon



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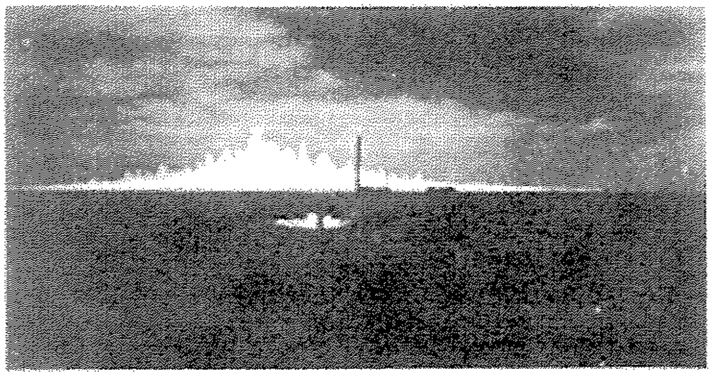
INITIAL SLICK EFFECTS

SLICK – THE TRACE OF AN ADVANCING SHOCK ON A CALM WATER SURFACE AS A CIRCLE OF DARK WATER RAPIDLY INCREASING IN DIAMETER



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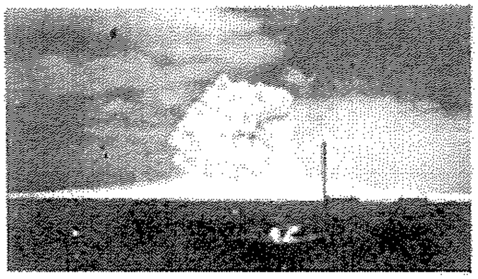
6.0 SEC

SECOND SPRAY DOME

SPRAY DOME – THE MOUND OF WATER SPRAY THROWN UP WHEN A SHOCK WAVE FROM AN UNDERWATER NUCLEAR BURST REACHES THE SURFACE.



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PLUME FORMATION

Figure I-3. Early time surface effects.

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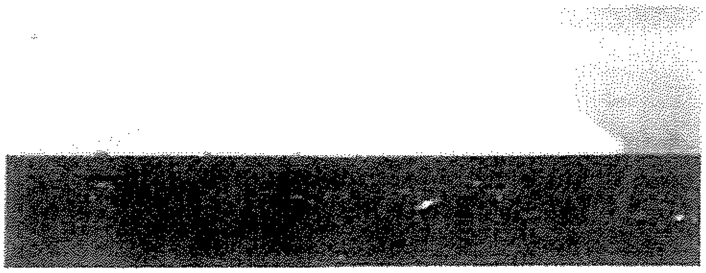
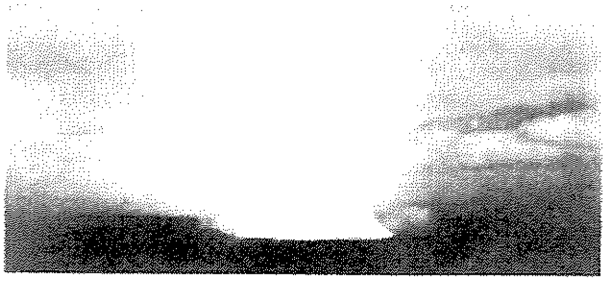


63 SEC

BASE SURGE AT EARLY TIMES



120 SEC

BASE SURGE AT LATE TIMES

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FOAM RING

Figure I-4. Late time surface effects.

- o Estimate the usefulness of this technique for determining the yield of future detonations
- o Attempt, by working back from the intensity and duration data, to calculate the temperatures of the shock wave (a close-in condition).

On D + 1 at 1000, PDT, the project officer boarded the YFNB-12 and recovered the magnetic tape record. Damage inside the transportainer was fairly extensive. No useful records were obtained from this project.

PROGRAM II - RADIOLOGICAL AND OCEANOGRAPHIC.

Project 2.1 Collection of Early Water Samples for Radiochemical Analysis and Yield Determination (Reference 26).

The objectives of Project 2.1, fielded by the Scripps Institution of Oceanography, were to:

- o Supply other agencies with seawater samples from the surface and just below the thermocline (400 feet) taken as early as possible post-shot
- o Make an airborne water-surface temperature survey in conjunction with an airborne radiological survey by Project 2.4 to make an early forecast of hydrodynamic and radiological conditions
- o Establish a floating range of drogue buoys across the shot site
- o Cooperate with Scripps Institution of Oceanography surface vessels in a long-term (3 to 4 days) survey of the distribution of radioactivity in the water.

Two survey aircraft flew in formation a prearranged pattern during the first 40 minutes post-shot, as shown in Figure I-5.

The following observations of the shot phenomenology were noted from memory, on the morning of D + 4, by the Project 2.1 observer in the ADS-N survey aircraft NR-92 (after it was found that the plane's wire recorder had failed to function during the initial survey flight). They are included due to the lack of photographic documentation for this period.

Visual impressions of the shot:

H-20 minutes. Weather 50 percent clear. Clouds cumulostratus, elevation 1800 to 2000 feet. Very large clearing over array 10 minutes prior to shot, but shot site in shadow at shot time. Flew east across array at H-10 minutes (just north of YC). Noted large kink in tow aft of YFNB-29. Could see (four ships) and tow clearly. Also could see the YAGs to the south. Could not see the moored skiffs.

H-hour. Pushed stopwatch and elapsed-time clock on radio UHF tone. First visible sign was the spray dome 150 feet by 1 mile, with 3 visible shock fronts traveling over water. No evidence of the shock was felt in the aircraft.

H + 4.2 seconds. Cone-shaped plume rising to 600 feet and falling back. Timed with a stopwatch.

H + 12 seconds. Large burst, fountain-shaped and symmetrical, 1500 feet high and 1500 feet in diameter.

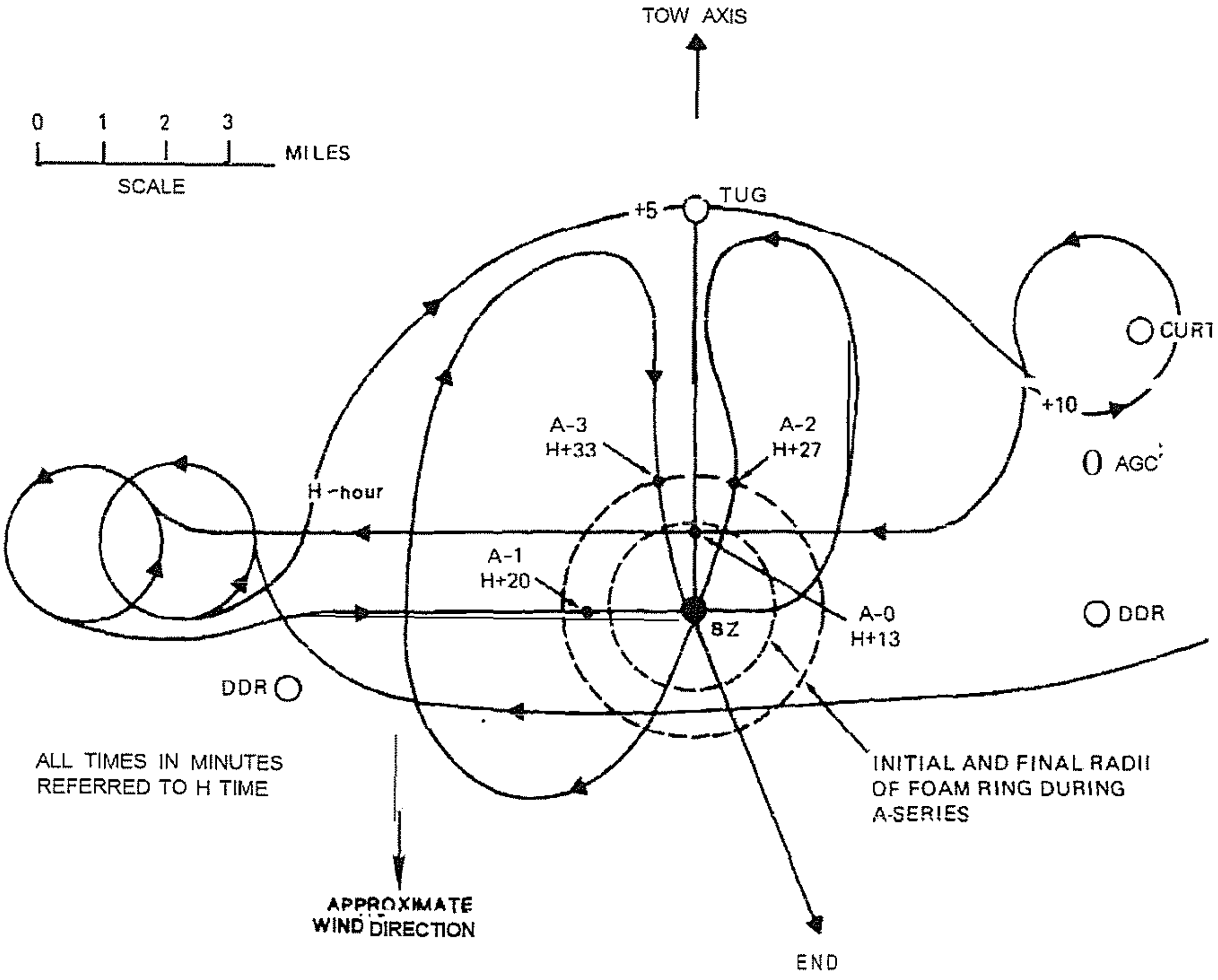


Figure I-5. Survey-aircraft flight plan for Able series passes across surface zero.

H + 30 seconds. Bulk of water had fallen back, leaving clouds of mist which blew off downwind. Surface trace consisted of perfect ring of pale-yellow foam 10 yards wide and 1-1/2 miles in diameter with relatively clean slick surface inside, speckled with a spider web of foam filaments aligned with the wind. Most of the debris was collected in the foam ring by approximately 10 o'clock. The green dye originally aboard the YC was about equally divided into two patches near the east and west extreme within the ring. The impression was that of a very strong convergence at the ring edge with a divergence at the center.

H + 4 minutes. All visible airborne material gone. Clouds closed in solidly over shot site.

H + 13 minutes. Approached from east to west on pass A-0 going exactly over the north edge of ring on a tangent course. Tow rope was crumpled up as far as YNFB-13, with three M-boats upside down. Foam ring still intact and expanding. Debris at west edge includes about ten or twelve 50-gallon drums, several orange or yellow towing floats, and two rubber drums. A pair of SQUAW pontoons floating 3 miles east of floating surface zero.

H + 20 minutes, A-1 pass. Ring intact, though ragged in south extreme. Dropped 11 samples (six shallow) at 1-second intervals, starting at 3 o'clock at the ring edge going east, speed 150 knots and altitude 500 feet.

H + 27 minutes, A-2 pass. All samples dropped on A-1 pass have drifted out to ring edge. Dye is moving east with respect to ring.

H + 33 minutes, A-3 pass. Saw YAG-40 steam north, distance two miles from ring. YAG-39 not moving. Survey 1 dropped 11 samples well distributed across foam ring.

H + 40 to H + 55 minutes.- Orbited, awaiting permission for Baker series. Ring has now expanded, crumpling array northward until YFNBs 12 and 13 lie close together and wire joining them streams out in a bight to the east. YAG-40 has altered course to east, cutting off only a small sector of the ring at about 5 o'clock. Only one drogue float is visible in her wake. M/V Horizon is still 5 miles away at 2 o'clock. Foam ring is now showing wide gaps and has become sinuous. Radioactivity is still associated with the two green dye spots which are now decidedly upwind of 'the foam ring.

H + 55 minutes to H + 2 hours. Carried out B and C series surveys at an altitude of 500 feet and a speed of 150 knots. A helicopter has surveyed the array, and now M-boats are approaching the YFNBs. Ring has largely disappeared, but dye remains. M/V Horizon is now closer (estimated distance, 2 miles). YAG-40 going back across area from southeast to northwest.

H + 2-1/2 hours. End of first survey flights.

Project 2.2 Radiochemical Analysis of WIGWAM Debris (Reference 27).

Project 2.2 was fielded by the Naval Research Laboratory. The objective of this project was to determine the effect of high pressures and the confining environment of a deep underwater explosion of an atomic device on such factors as yield, efficiency, induced activities, fission-yield ratios, fractionation, etc.

The shot WIGWAM underwater detonation caused no unexpected effects on the relative fission yields of the various isotopes or on other elements in its environment.

Project 2.3 Radiochemical and Physical Chemical Properties of Products of a Deep Underwater Nuclear Detonation (Reference 28).

The U.S. Naval Radiological Defense Laboratory attempted to make the following determinations from samples of surface water, deep water, and airborne material:

- Total beta and gamma activity and distribution of radioactivity
- Radiochemical composition and gross beta-ray decay rates
- Valence state of selected radionuclides.

Radiation contours are shown for H + 0.33 hours, H + 1.4 hours, H + 20.4 hours and H + 26 hours in Figure I-6.

Project 2.4 Determination of Radiological Hazard to Personnel (Reference 6).

The objective of Project 2.4, fielded by the U.S. Naval Radiological Defense Laboratory, was to obtain information pertinent to the determination of the radiological hazard to personnel on board ships traversing a zone of water contaminated by a subsurface atomic weapon burst.

The objectives were attained by means of the following measurements:

- The size, shape, location and radiation characteristics of the radioactivity-contaminated area as a function of time
- The gamma-radiation intensity at specific stations throughout a ship, during and subsequent to traverses through the area
- The extent of residual contamination on the hull and exposed surfaces of the ships, the performance of the washdown system, and the effectiveness of various contamination countermeasures.

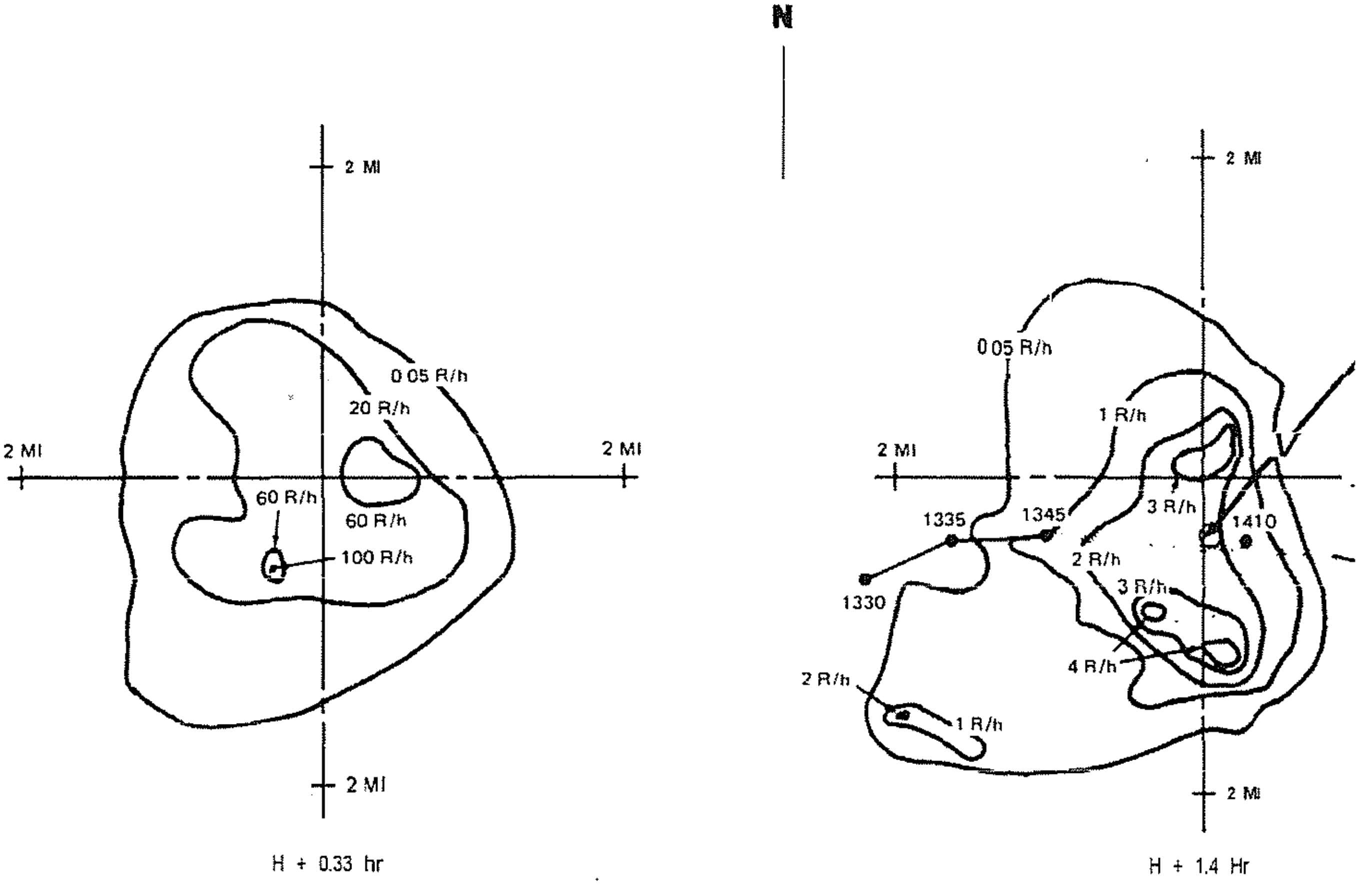
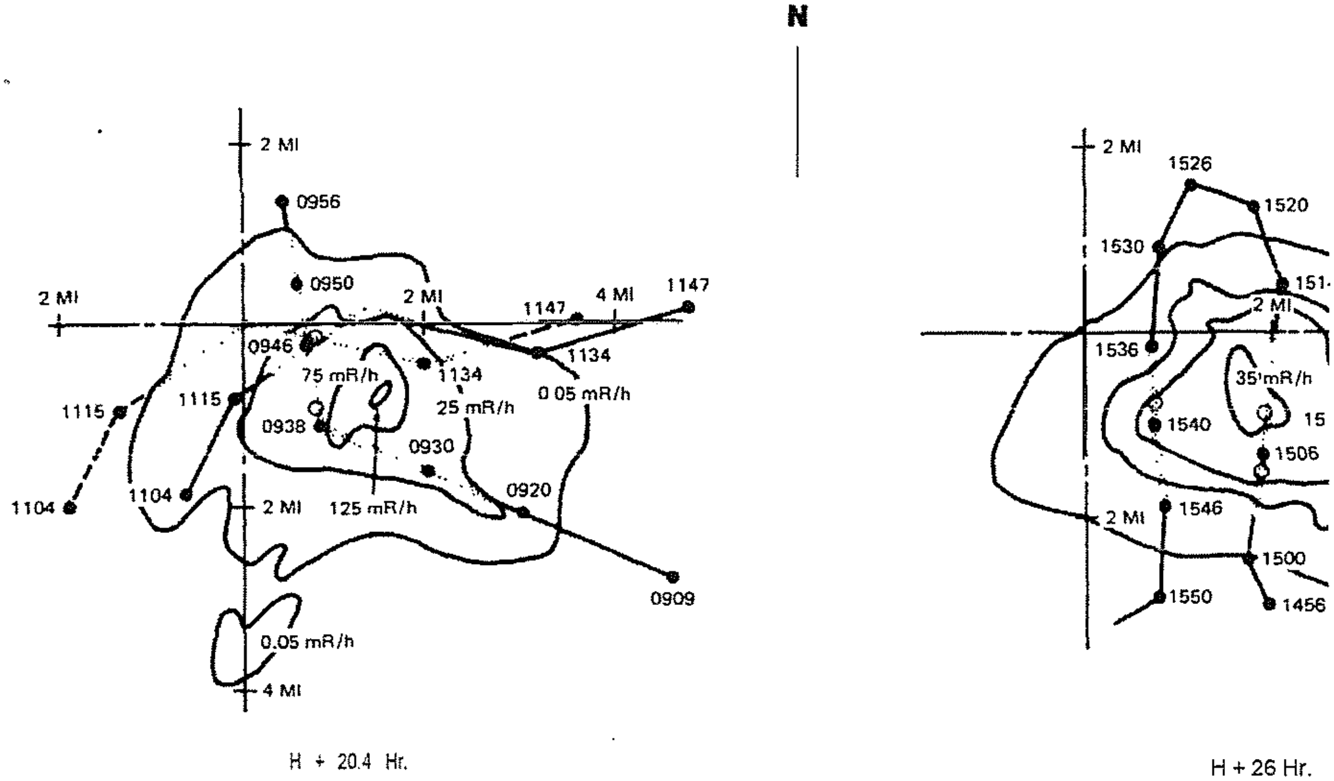


Figure I-6. Radiation Contours. The heavy stippled line (right) indicates the times at which the YAG-40's detection system sensed radioactivity in the water.



H + 20.4 Hr.

H + 26 Hr.

Figure I-6. (Continued). The heavy stippled lines indicate the times at which the YAG-40's detection system sensed radioactivity in the water. The open circles indicate the locations of the ship at sample collection time.

The principal ships used to support this project were the YAG-39, YAG-40, and ATF-106. A Navy TACRON unit, which was located on AGC-7, provided the necessary radar control for the survey aircraft.

Sections D-4 and D-5 of Appendix D of this report discuss the data obtained from this project. The radiological situations actually encountered by YAG-39 and YAG-40 cannot be considered tactically serious unless similar situations were to be encountered frequently. The extrapolated situation at early times may be of tactical significance. The radiological situation changed extremely rapidly, and the hazard decreased accordingly.

Project 2.5 Effects of Nuclear Explosion on Marine Biology (Reference 29).

The Scripps Institution of Oceanography fielded Project 2.5. The objectives of this project were to:

- Conduct studies of the distribution of marine organisms in or near the proposed area to provide information which would make possible the selection of a test site such that the hazard to the fisheries would be minimal
- Conduct laboratory studies on the uptake of fission products by fish and other marine organisms in order to have more knowledge of the ingestion of such products from seawater and their retention and excretion by the organisms
- Participate in field studies following the test to investigate the ingestion of resulting fission products by marine organisms.

It was shown that, except in the portions of the area immediately adjacent to the coast, the region is low in phytoplankton, zooplankton, forage fish, and large pelagic fish. The north-western part of the region of study, in the vicinity of 123°W, 28°N, was particularly barren.

Long-line fishing in the vicinity of the test site, immediately pre- and post-test confirmed the absence of a significant number of tuna or other large pelagic commercial fish in the area at the time of the test.

Studies of ingestion, retention, excretion, and sites of deposition of Sr^{90} in a representatiave pelagic food fish, the Pacific mackerel (Pneumatophorus diego), were undertaken by feeding it with this isotope and studying the total activity and its distribution in various organs after various periods of time (up to 235 days). It was found that 95 percent of the activity was excreted in 24 hours but that the remaining 5 percent remained fixed in the body for the duration of the experiment.

Project 2.6 (Part 1) Mechanism and Extent of the Early Dispersion of Radioactive Products in Water (Reference 7).

The Scripps Institution of Oceanography fielded Project 2.6. This project measured the radioactivity and temperature of the seawater from three oceanographic vessels and several aircraft. The circulation of the water at various depths was determined by drogues referred to moored instrument stations.

Measurements of the radioactivity at the surface and the surface water temperature were obtained by the survey aircraft.

The aircraft surveys were particularly valuable in the determination of: (1) surface activity at early times, and (2) the area of the radioactive surface layer.

Section D-4, Appendix D of this report contains the results of this project.

Project 2.6 (Part 2) Mechanism and Extent of the Dispersion of Fission Products by Oceanographic Processes and Locating and Measuring Surface and Underwater Radioactive Contamination (Reference 30).

Three weeks after the detonation, the ship M/V Baird, under the auspices of the Scripps Institution of Oceanography, surveyed the water mass contaminated by the WIGWAM event; it was larger and less active than anticipated.

Project 2.6 (Part 3) Radiological Techniques and Instruments Used for the Oceanographic Survey on Operation WIGWAM (Reference 31).

This report by the Scripps Institution of Oceanography gives a brief description of the instruments and measuring techniques used in surveying the water influenced by the Shot WIGWAM detonation.

Project 2.7 Fallout and Airborne Activity in Operation WIGWAM, with notes on Surface Effects (Reference 5).

The U.S. Naval Radiological Defense Laboratory fielded Project 2.7. The principal objective of this project was to gather and correlate information bearing on the fallout from Operation WIGWAM. Secondary objectives included (1) zero-point dosage measurement and (2) dye-marking of surface zero.

Fallout-collecting and gamma-recording equipment was placed aboard the YAG-39 and YAG-40. Then fallout stations were situated on two converted LCM's and the YFNB-12 which were in tow with the shot barge. Ten floats containing instruments for ascertaining zero-point dosage were placed aboard the shot barge to be released at H - 1 minutes.

The WIGWAM test showed that if deep underwater bursts are employed in wartime situations, it is possible for significant doses to be received from airborne activity by exposed personnel directly downwind of surface zero and within a few miles of it. Risk of this exposure from airborne activity exists only during passage of the base surge or fallout cloud. Such risk can be reduced tactically by any of several measures (e.g., by keeping ship/aircraft off the downwind axis, by keeping personnel off topside areas, by buttoning up ship/aircraft, by moving units farther downwind, etc.)

Likewise, the WIGWAM test showed that if deep underwater bursts are employed in wartime situations, it is possible for significant doses to be received from contaminated water near surface zero. Risk of this exposure decreases rapidly with time. For example, Figure I-6 shows that 20 minutes after the detonation there were small patterns (less than a mile in diameter) with exposure rates of 60 R/h, while 20 hours after the detonation the highest exposure rate was a very small area of 0.125 R/h. See also Appendix D. These risks can be reduced tactically simply by avoidance of these small areas immediately after the detonation.

Project 2.8 (Part 1) Subsurface Configuration of the Array (Reference 32).

In January 1955, four months before the WIGWAM shot, towing trials were conducted by the Scripps Institution of Oceanography off San Clemente Island, California, to verify the applicability of calculating the underwater profile of a suspended instrumentation string. As a result of these trials, towing speeds were suggested between the limits defined by the scientific agencies as well as by consideration of seamanship.

Project 2.8 (Part 2) Physical Oceanography of the Test Area (Reference 33).

The Scripps Institution of Oceanography fielded Project 2.8, Part 2. The objectives of this project were to assist in the selection of a test site, to provide information for predictions of phenomenology, and to document environmental information concerning Operation WIGWAM.

Oceanographic and experimental fishing cruises were made during 1954 over a large open sea area southwest of San Diego, California, to select the site for the Operation WIGWAM.

Results of post-shot surveys concluded that:

- Contaminated waters moved westward from the test site at an average speed of about 0.1 knot (away from shore and fishing grounds)
- Dispersion of radioactivity at a given level was relatively slow during the first 10 days, but current shear augmented its spreading
- Depth of radioactivity measured at various times after the event appeared intimately associated with stability or vertical density gradient in the water
- At zero hour the array and most ships of the task force were over relatively flat sea bottom, but a ridge 0.75 mile high existed about 5 miles south of surface zero. The low current speeds and movement of water away from land and ocean fishing grounds at the test area were desirable conditions.

Project 2.9 Measurement of Secondary Effects: Water Waves (Reference 34).

Project 2.9 was fielded by the Scripps Institution of Oceanography. It had three objectives:

- To assist in obtaining data about the post-shot submergence and distribution of radioactivity
- To measure and study the resultant water waves, and
- To place moored surface buoys near surface zero for navigational aids

The project developed and used instrumentation and techniques that permitted the horizontal search and survey of radioactivity at depths of 500 feet and speeds up to 6 knots.

Project instrumentation for water-wave measurement was inoperative at shot time, and subsurface pressure-time measurements were not obtained. Photographic data have yielded sufficient surface elevation-time data for a study of the resultant water waves.

Surface moorings as navigational aids were positioned near surface zero. A sufficient number were successful to relate post-shot activities with geographical surface zero.

Program III - TARGET RESPONSE

Project 3.1 Lethal Range of WIGWAM Targets Based on Hull Response and Applied Pressure Measurements (Reference 35).

A major objective of the Operation WIGWAM was to determine the lethal range for an atomic depth charge against a typical submarine target. This knowledge was of military importance as a guide to proper tactics in using the weapon against enemy submarines and also in protecting the United States ships against such attack.

Under Project 3.1, measurements were made by the David Taylor Model Basin of the response of the pressure hulls of three submarine targets to the attack. Primarily the measurements were intended as one basis for lethal-range estimates. For this purpose it was planned that the measurements would supplement (1) a detailed examination of the damage after the test and (2) high-speed photographs of the damage taken during the test. In addition, the plan was that the measurements would verify, or perhaps elaborate, the theoretical concepts of the damage mechanism which had been formulated previously. Some knowledge of this damage mechanism was necessary in order to extrapolate any single measurement of the lethal range to other targets or other conditions of attack.

The external pressures applied to the three SQUAW targets (see Figure I-7) in Operation WIGWAM were measured with pressure gages, and the deformations of the hull were measured with strain and displacement gages.

The results indicate that SQUAW-12 was destroyed, probably within 10 msec. The hull of SQUAW-13 was severely damaged and was near collapse but it did not rupture. The lethal range of a SQUAW target was estimated for the Shot WIGWAM test conditions and a general formula proposed which gave conditions for a lethal attack by an atomic depth charge against a full-scale submarine.

Project 3.2 (Parts 1 and 2) Hull Response and Shock Motion--Background, Instrumentation, and Test Results--Discussion and Analysis (References 36 and 37).

The David Taylor Model Basin fielded Project 3.2. The objectives of this project were to provide instrumentation and make measurements on SQUAW and YFNBs necessary to determine:

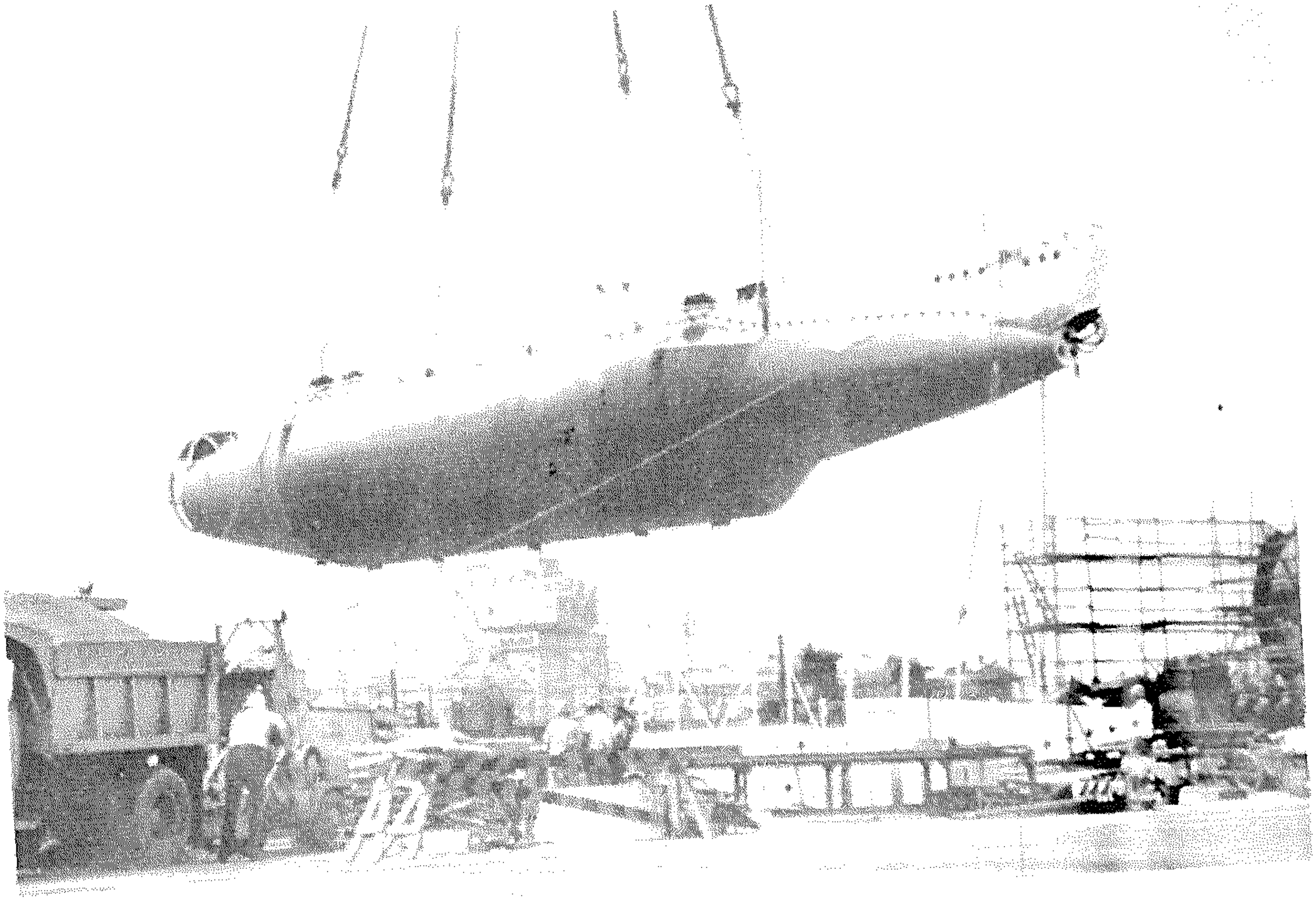


Figure 1-[illegible]. Lowering of Cabin.

- The rigid body motion of the hull as a function of time
- The motion of the hull at representative locations as a function of time
- The motion of simulated items of ship's heavy machinery as a function of time
- Shock spectra at representative locations on the vessels
- Analyze and interpret the results obtained.

One hundred forty velocity meters, 12 accelerometers, 132 shock-spectrum records, and 72 mechanical displacement gages were installed on three SQUAWs and three YFNBs (see Figure I-8) for the measurement of hull response and shock motions.

Project 3.2.1 Shock Motion of YFNB Targets (Reference 38).

Reed gages were placed by the U.S. Naval Research Laboratory on the YFNB targets to measure the severity of shock motions. These data were expected to be helpful in working out a prediction of the shock damage to surface ships caused by a deep atomic explosion.

Project 3.3 Vibration Characteristics of Certain Items on SQUAW-29, YFNB-20, and PAPOOSE C (Reference 39).

The objective of this project, fielded by the David Taylor Model Basin, was to obtain the vibration characteristics of the SQUAW, YFNB, and PAPOOSE C (a 1/5.33-scale model of the SQUAW) targets.

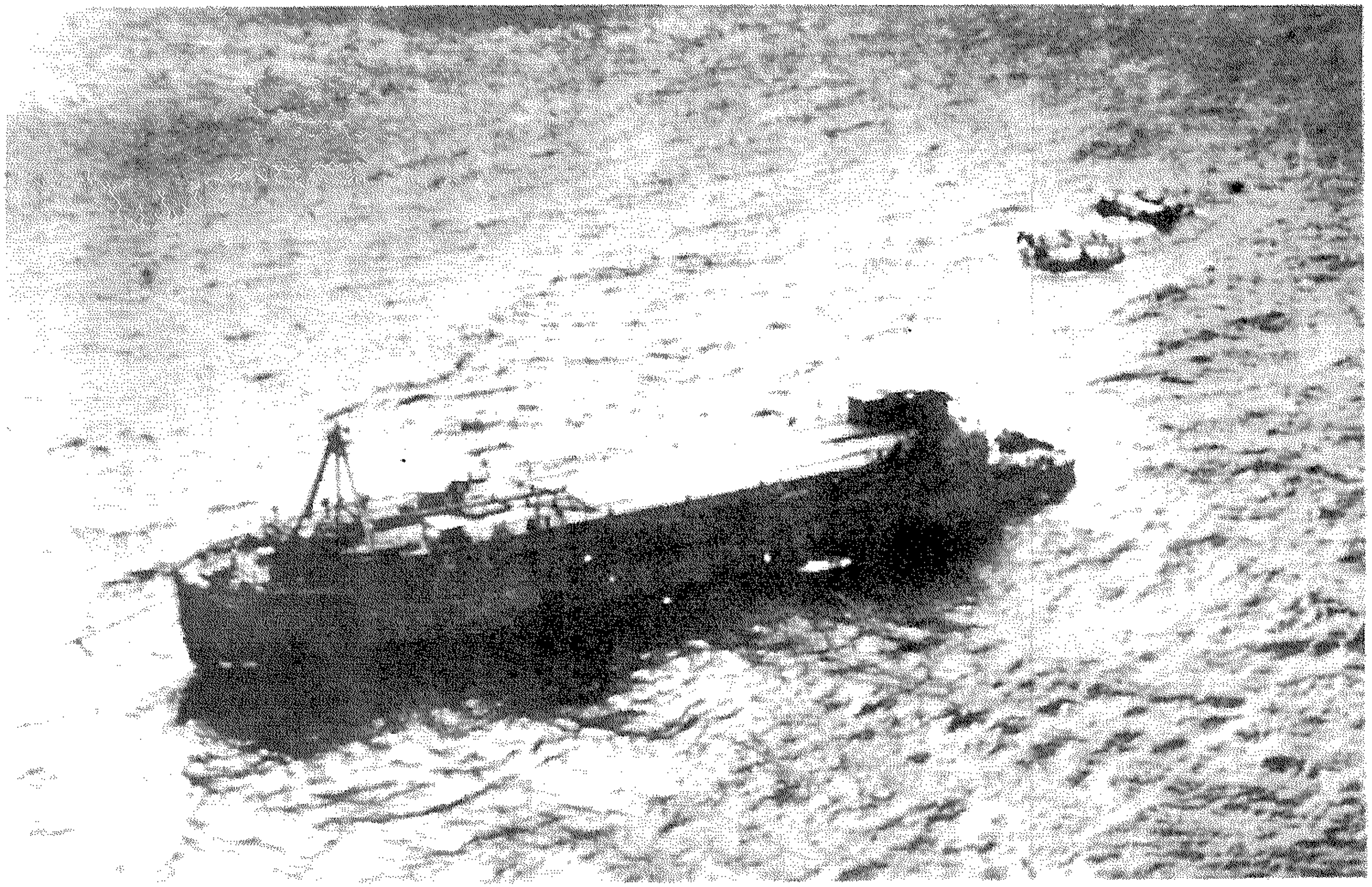


Figure I-9. YFNB-12.

These tests were conducted in 1954 in preparation for the Operation WIGWAM.

Project 3.4 Response to SQUAW Targets from High-Speed Motion Pictures of Interior (Reference 40).

Project 3.4 was fielded by the David Taylor Model Basin. The objective of this project was to obtain high-speed motion pictures of critical portions of the hull and the simulated equipment in the test compartments of each SQUAW target.

Film records were recovered from SQUAW-29. The SQUAW-12 cameras and film sank with the ship immediately after the explosion. The camera and film from SQUAW-13 were lost when SQUAW-13 sank during tow from the test area to the salvage area.

Project 3.6 Depth, Trim, Heading and Flooding of WIGWAM Targets (Reference 41).

The David Taylor Model Basin fielded Project 3.6. The objective of this project was to determine at zero time, the angles of roll and pitch, the heading, and the occurrence of flooding in all of the SQUAW target compartments.

Project 3.8 Design and Construction of WIGWAM Targets (Reference 42).

Three simplified submersible submarine-type hulls were designed and constructed by the Long Beach Naval Shipyard. All three were nearly identical. These vessels were required to be towed on the surface, then to be submerged to a 250-foot depth, to be towed submerged, and then to be raised to the surface.

The raising and lowering of each SQUAW was done by means of compressed air supplied from a YFNB that also served as the instrument barge for the recording devices installed on the SQUAWS by the David Taylor Model Basin.

Each SQUAW, when submerged, was supported by a group of eight 80-ton salvage pontoons, as shown in Figure I-9.

Towing was from the YFNB. Two tow wires were directed from winches on the stern of the YFNB--one to a towing pad at the forward end of the SQUAW and the other passing over the SQUAW to the pontoons.

In addition to the five salvage hoses leading from the SQUAWs to the YFNBs, there were three instrumentation cables. The distance from the nose of a SQUAW to a YFNB was 600 feet.

Project 3.9 Modification and Outfitting of Instrumentation Barges (Reference 43).

This project, fielded by the Navy Electronics Laboratory, was nonexperimental in nature and was primarily intended to support the scientific effort planned for the barge locations in the array. Main objectives of the project were:

- o To modify and equip three YFNB barges (see Figure I-10) as surface control stations for the three submersible targets (SQUAWs) constructed under Project 3.8.
- o To provide facilities aboard the three YFNBs to support the remote recording instrumentation associated with these submarine targets under Program III (primarily the responsibility of the David Taylor Model Basin).
- o To support the instrumentation of other scientific projects concerned with experimental work in the vicinity at the barge locations.

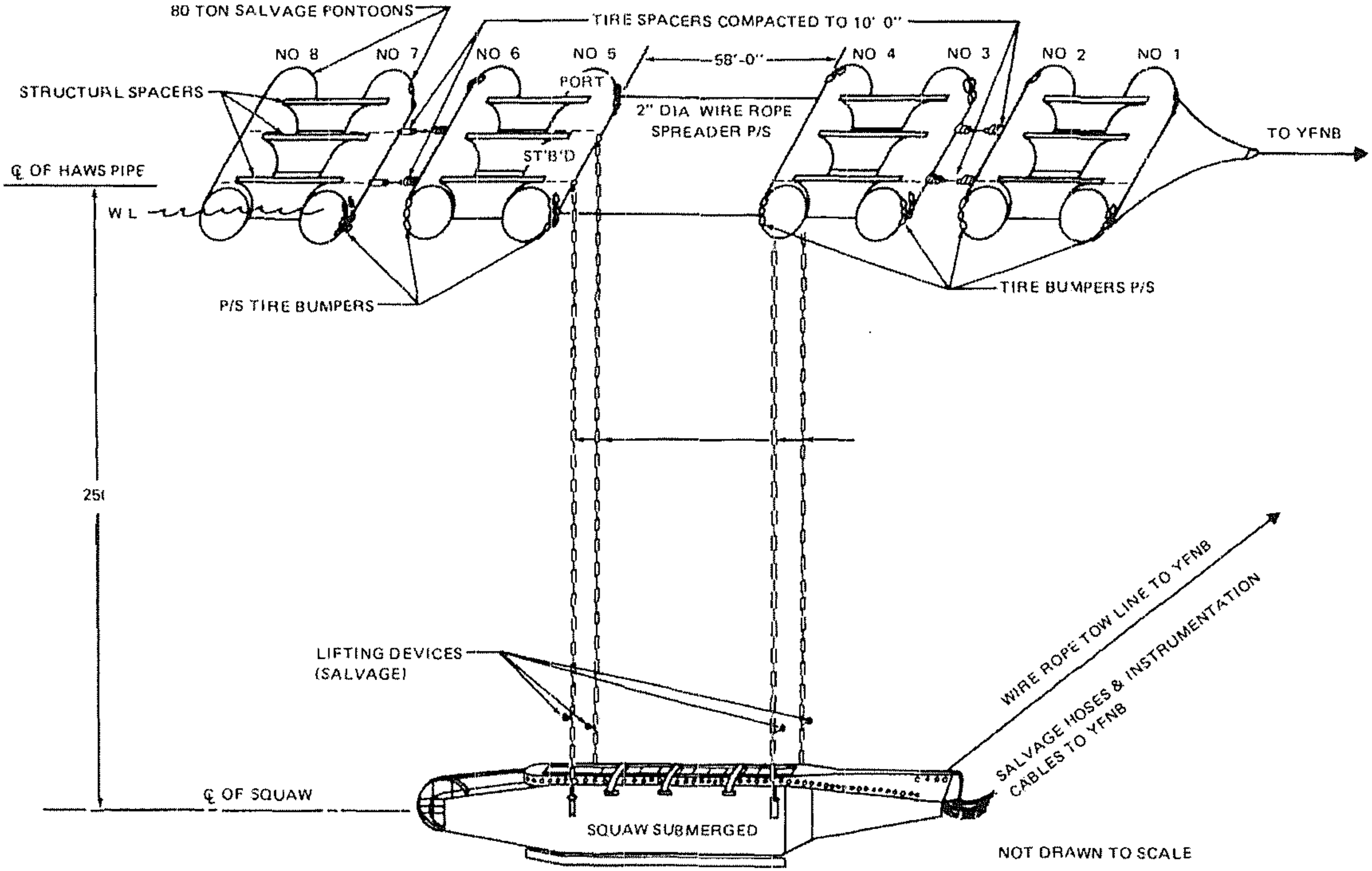


Figure I-9 Suspension and towing arrangements for SQUAW.

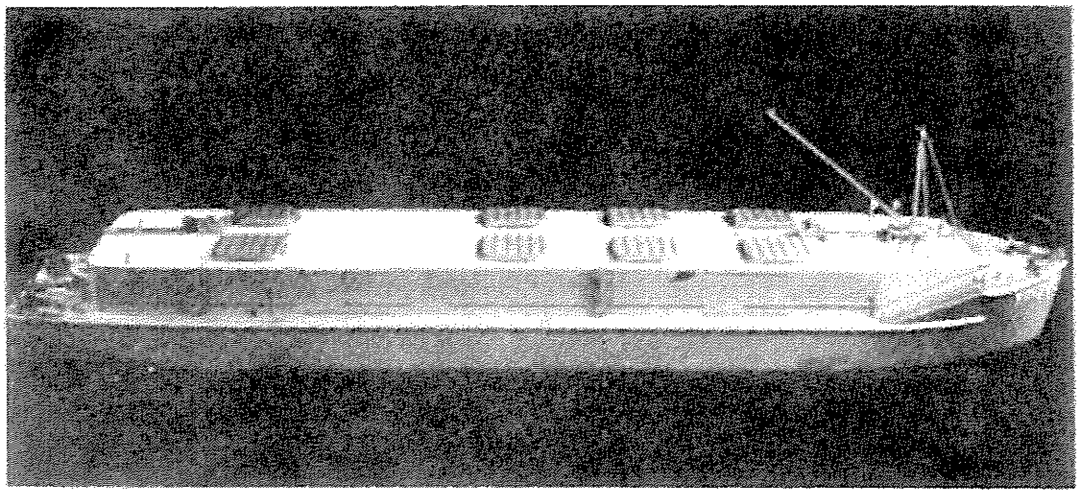


Figure 1-10. Model of YFNB barge.

APPENDIX I
OPERATIONS PROJECTS
(Continued)

SUPPORT PROJECTS.

PROGRAM IV - WEAPON CHARACTERISTICS.

Project 4.1 - Weapon Placement at Operation WIGWAM (Reference 44).

The purposes of this project were to specify the type of barge to support the weapon, and to provide the bomb case, electrical system, and bomb handling equipment.

The zero barge was towed to the site and final arming preparations were commenced at H-9 hours, and completed at H-3 hours with submergence of the unit to the 2,000-foot depth. There were no recovery operations.

Project 4.2 Weapons Assembly (Reference 45).

The objective was to procure, assemble and arm the required weapon in the watertight case provided by Project 4.1 and to supervise its placement at a depth of 2,000 feet.

The weapon detonated as planned. There were no recovery operations.

Project 4.3 - Radiochemical Determination of Yield

This project attempted to determine the fission yield of the weapon by radiochemical analyses of water samples.

The results gave a yield of 32 ± 1 KT. No recovery operations were involved since the required water samples were provided by another project (Project 2.1).

Project 4.4 - Close-in Time of Arrival of Underwater Shock Wave (Reference 46).

In this project, the objective was to determine several hydrodynamic variables of the shock wave from measurements of time of arrival at close-in distances where the shock was sufficiently strong to be supersonic.

The measurements were successful and agreed well with theory. With the knowledge of the hydrodynamic variables, it was possible to deduce a yield of the weapon. This was 31.7 ± 1.2 KT.

No recovery operations were required.

Project 4.5 - Air Pressures from a Deep Underwater Burst (Reference 47).

This project was to investigate pressures in the air produced by a deep underwater burst. Because of the bad weather, only a small portion of the desired data was obtained.

APPENDIX J

NAVY ENLISTED CLASSIFICATIONS TABLES

APPENDIX J
NAVY ENLISTED CLASSIFICATIONS TABLES

Table J-1. Dosage distribution for airborne units.

UNIT/ORGANIZATION	TOTAL PERSONNEL	NUMBER DOSIMETRY UNAVAILABLE	ZERO DOSE NUMBER	DOSAGE CATEGORY (mR)							
				100	130	165	200	240	280	315	42
AIR UNIT PERSONNEL											
1. vc-35	18	0	16	0	0	0	0	0	1	0	1
2. MAG 36/HMR 362	49	3	37	5	2	0	0	0	1	1	0
3. HU-1	5	2	0	0	3	0	0	0	0	0	0
4. VP-46	1	0	0	0	1	0	0	0	0	0	0
5. VC-61	2	0	1	0	1	0	0	0	0	0	0
6. VP-2	142	1	131	7	2	0	0	0	1	0	0
7. USAF	15	0	1	5	9	0	0	0	0	0	0
8. VU-J	2	0	0	1	1	0	0	0	0	0	0
9. vs-21	26	8	17	1	0	0	0	0	0	0	0
SUBTOTAL	260	14	203	19	19	0	0	0	3	1	1
PERCENT	100%	5.4	78.1	7.3	7.3	0	0	0	1.2	0.4	0
AIR PASSENGERS											
10. VP-2	33	1	21	0	0	0	0	0	6	5	0
PERCENT	100%	3.0	63.6	0	0	0	0	0	18.2	15.2	0
TOTAL	293	15	224	19	19	0	0	0	9	6	1
PERCENT	100	5.1	76.5	6.5	6.5	0	0	0	3.1	2.0	0

APPENDIX J
NAVY ENLISTED CLASSIFICATIONS TABLES
(Continued)

Table J-2. Dosage distribution for technical personnel.

UNIT/ORGANIZATION	TOTAL PERSONNEL	NUMBER DOSIMETRY UNAVAILABLE	ZERO DOSES	DOSAGE CATEGORY (mR)						
				100	130	165	200	240	280	315
1. **Lookout MTN Lab (USAF)**	**14**	0	12	0	0	0	0	0	0	2
2. Oak Ridge Nat Lab (AEC)	3	0		0	[illegible]	0	0	0	0	1
3. NRDL (NAu)	54	1	43	5	0	2	0	0	1	0
4. Scripps Inst. of Oceanography (Navy)	41	7.	17	2	8	4	0	1	0	1
5. NEL (Navy)	126	3	120	1	1	0	1	0	0	0
6. Hydrographic Office (Navy)	1	0	0	0	1	0	0	0	0	0
7. Bu Ships (Navy)	6	0	5	0	1	0	0	0	0	0
8. Shipyards (Navy)	27	0	20	2	5	0	0	0	0	0
9. NOL (Navy)	31	1	26	4	0	0	0	0	0	0
TOTAL	303	12	244	14	17	6	1	1	1	4
PERCENT	100	4.0	80.5	4.6	5.6	2.0	0.3	0.3	0.3	1.3

APPENDIX J
NAVY ENLISTED CLASSIFICATIONS TABLES
(Continued)

Table J-3. Dosage distribution for shipboard personnel.

SHIP/UNIT	TOTAL ABOARD	DOSIMETRY UNAVAILABLE	ZERO DOSES NUMBER	DOSAGE CATEGORY (mR) 100	130	165	200	240	280	315	35
1. M/V Horizon (SIO)	18	4	0	8	5	0	1	0	0	0	0
2. USS CHANTICLEER (ARS-7)	96	0	15	34	39	7	1	0	0	0	0
3. USS TAWASA (ATF-92)	73	0	35	26	10	0	1	1	0	0	0
4. USS BOLSTER (ARS-38)	91	0	65	22	2	0	1	0	0	0	0
5. Amphibious Base Coronada (Boat Pool)	230	18	181	28	2	0	0	0	1	0	0
6. USS GEO EASTMAN (YAG-39)	48	1	41	2	4	0	0	0	0	0	0
7. USS FRANK E. EVANS (DD-754)	269	27	241	1	0	0	0	0	0	0	0
8. USS WRIGHT (CVL-49)	974	45	839	25	9	2	0	0	0	0	0
9. M/V Spencer F. Baird (SIO)	16	0	15	1	0	0	0	0	0	0	0
10. USS ALFRED A. CUNNINGHAM (DD-752)	268	12	252	3	1	0	0	0	0	0	0
11. USS CURTISS (AV-4)	573	17	551	4	1	0	0	0	0	0	0

APPENDIX J
NAVY ENLISTED CLASSIFICATIONS TABLES
(Continued)

Table J-3. Dosage distribution for shipboard personnel.

SHIP/UNIT	TOTAL ABOARD	DOSIMETRY UNAVAILABLE	ZERO DOSES NUMBER	DOSAGE CATEGORY (mR)						
				100	130	165	200	240	280	315
12. USS MCKEAN (DDR-784)	256	3	248	3	1	0	1	0	0	0
13. USS MCKINLEY (AGC-7)	552	9	538	4	1	0	0	0	0	0
14. USS MOCTOBI (ATF-105)	69	0	67	2	0	0	0	0	0	0
15. USS GRANVILLE HALL (YAG-40)	48	0	47	0	1	0	0	0	0	0
16. USS HITCHITI (ATF-103)	76	0	75	1	0	0	0	0	0	0
TOTAL	3,567	137	3,264	164	76	9	5	1	1	0
PERCENT	100	3.7%	89.3%	4.5	2.1	.2	.1	.03	.03	0

APPENDIX J
NAVY ENLISTED CLASSIFICATIONS TABLES
(Continued)

Table J-4. Dosage distribution for miscellaneous units.

	UNIT/ORGANIZATION	TOTAL PERSONNEL	DOSIMETRY UNAVAILABLE	ZERO DOSES NUMBER	DOSAGE CATEGORY (mR) 100	130	165	200	240	280	315	M O
1.	NAS Pearl Harbor	1	0	0	1	0	0	0	0	0	0	
2.	FAW-1 Okinawa	1	0	0	0	1	0	0	0	0	0	
3.	FAS-110	2	0	1	0	1	0	0	0	0	0	
4.	TUGRON-1	17	0	15	2	0	0	0	0	0	0	
	TOTAL	21	0	16	3	2	0	0	0	0	0	
	PERCENT	100	0	76.2	14.3	9.5	0	0	0	0	0	

APPENDIX J
NAVY ENLISTED CLASSIFICATIONS TABLES
(Continued)

Table J-5. Dose (mR) vs Job Category.

(Total Enlisted Exposure-237)

RATING GROUP

AVIATION	TOTAL	100	130	165	200	240	280
AA Apprentice	1	1	0	0			0
AB Boatswains	1	1	0	0	0	0	0
AD Machinists	4	1	3	0	0	0	0
AE Electrician	1	1	1	0	0	0	0
AK Storekeeper	2	1	0	0	0	0	0
AL Electronicsman			1	0			0
AN Airman	5	3	2	0	I	0	0
AT Electronics Tech	6	3	2	0		0	1
AVIATION TOTAL			9	0	0	0	1
% OF ENLISTED EXPOSURES	29	14.6	3.8	0	0	0	0.4

DECK CREWS	TOTAL	100	130	165	200	240	280
		0					
CHBOSN Chief Boatswain	3	16	2	0	1	0	0
BM Boatswain	22		3			0	0
SN Seaman	46	30		2	1	1	0
SA Seaman Apprentice	31	22	126	23	1	0	0
DECK TOTAL	102	68	23	7	3	1	0
% OF ENLISTED EXPOSURES	43	29	10	3	1	0.4	0

FIREMEN	TOTAL	100	130	165	200	240	280
FN Fireman				0			0
FA Fireman Apprentice	29	21	8	0	0	0	0
FIREMEN TOTAL	33	25	8	0	0	0	0
% OF ENLISTED EXPOSURES	14	10.5	3.4	0	0	0	0

ENGINE SPACES	TOTAL	100	130	165	200	240	280
CHMACH Chief Machinist	3	3	0	0	0	0	0
MN Machinist	5	2	3	0	0	0	0
MR Machinist Repairman	9	4	5	0	0	0	0
EN Engineman	17	10	5	1	1	0	0
BT Boilerman	1	0	1	0	0	0	0
				1	1		
ENGINE TOTAL	35	19	14	0.4	0.4	0	0
% OF ENLISTED EXPOSURES	15	8.0	5.9			0	0

APPENDIX J
NAVY ENLISTED CLASSIFICATIONS TABLES
(Continued)

Table J-5. Dose (mR) vs Job Category.

(Total Enlisted Exposure--237)

RATING GROUP

ALL OTHERS	TOTAL	100	130	165	200	240	280
AG Aerographic	1	1	0	0	0	0	0
CA Construction Apprentice	1	0	1	0	0	0	0
CS Commissary	2	1	1	0	0	0	0
DC Damage Controlman	5	3	2	0	0	0	0
DN Dental	1	1	0	0	0	0	0
EM Electricianman	11	6	4	1	0	0	0
ET Electrician Technician	6	5	1	0	0	0	0
FT Fire Control Technician	2	1	1	0	0	0	0
HM Hospital Corps.	2	1	1	0	0	0	0
PH Photographer	3	2	1	0	0	0	0
QM Quartermaster	2	0	2	0	0	0	0
RD Radarman	2	1	1	0	0	0	0
SD Steward	1	1	0	0	0	0	0
SK Storekeeper	1	1	0	0	0	0	0
SO Sonarman	1	1	0	0	0	0	0
TN Steward	2	1	1	0	0	0	0
TA Steward Apprentice	1	1	0	0	0	0	0
YN Yeoman	1	0	1	0	0	0	0
CHGUN Chief Gunner	1	0	1	0	0	0	0
OTHERS TOTAL	46	17	18	1 0.4	0	0	0
% OF ENLISTED EXPOSURES	19	11.4	7.6		0	0	0

Table J-6.
List of Units/Organizations Whose Personnel Received Zero Dose.

Table J-6A. - Air Support Units.

UNIT/ORGANIZATION	TOTAL PERSONNEL	NO. W/O RECORDS*
VC-11 NAS North Island	1 mil	0
VR-3 NAS Moffett Field	3 mil	0
TOTAL AIR SUPPORT PERSONNEL	4 mil	0 w/o records

Table J-6B. - Technical Organizations.

UNIT/ORGANIZATION	TOTAL PERSONNEL	NO. W/O RECORDS*
DTMB	11 civ	0
NAVORD Test Station Pasadena	9 civ	5
NRL, Wash., D.C.	11 civ	0
EGG, Las Vegas	9 civ	1
EGG, Boston	4 civ	0
Sandia Corp	23 civ	0
Armour Research Foundation	8 civ	0
TOTAL TECHNICAL PERSONNEL	75 civ	6 w/o records

* Included in the Total column.

APPENDIX J
NAVY ENLISTED CLASSIFICATIONS TABLES
(Continued)

Table J-6.
List of Units/ Organization
Whose Personnel Received Zero Dose.

Table J-6C. - Ships.

UNIT	TOTAL PERSONNEL	NO. W/O RECORDS*
uss BLUE (DD 744)	266 mil	5
USS ERNEST G SMALL (DD 838)	265 mil	2
USS HARRY E HUBBARD (DD748)	258 mil	9
USS O'BRIEN (DD 725)	285 mil	4
USS WALKE (DD 723)	261 mil	3
USS FORT MARION (LSD 22)	279 mil	2
USS COMSTOCK (LSD 19)	241 mil	11
USS CREE (ATF 84)	68 mil	0
USS MOLALA (ATF 106)	76 mil	9
USS RECLAIMER (ARS 42)	78 mil	2
USS LST 975	100 mil	1
USS LST 1048	96 mil	4
USS BUTTERNUT (AN-9)	42 mil	1
T-Boat (Scripps)	5 civ	4
M/V Paolina - T (Scripps)	10 civ	0

TOTAL CREW 2315 mil + 15 civ = 2330 57 w/o records

* Included in the Total column.

Table J-6.
List of Units/ Organization
Whose Personnel Received Zero Dose.

Table J-60. - Miscellaneous Observer/Participant.

UNIT/ORGANIZATION	TOTAL PERSONNEL	NO. W/O RECORDS*
SHIPYARDS		
Charleston	2 civ	0
Pearl Harbor	2 civ	0
Portsmouth	2 civ	0
Puget Sound	2 civ	0
Naval Air Stations/Naval Stations		
NS Midway Island	2 mil	0
SWV PAC NAS North Island	1 mil	0
NAVAL STAFF/OBSERVERS		
CNO (OP 363)	1 mil	0
COMFIRSTFLT STAFF	1 mil	0
COMSUBDIV 52	1 mil	0
COMTASKFORCESEVEN	1 mil	0
BUMED	2 mil	0
BU ORD	1 mil	0
COMNAVAIR PAC	1 mil	0
USS HANCOCK (CVA 19)	3 mil	0
USS BURTON ISLAND AGB-1)	1 mil	0
USS PT CRUZ CVS 119)	2 mil	2
uss NORTON SOUND (AVM-1)	3 mil	0
CSO Brooklyn NY	1 civ	0
DSDS Wash., D.C.	1 mil	0
NAV Powder Factory Indian Head	1 civ	0
NAV Biological Lab Oakland Supply Depot	1 mil	0
NAVGUN FAC D.C.	1 mil	0
OASD (R&D)	1 civ	0
Wright Air Dev	1 civ	0
REC STAT NAVY #128	1 mil	0
ARMY OBSERVERS		
Dept of Army	1 mil	0
Aberdeen Proving Grounds	1 mil	0
Army Chemical Center	1 civ	0

* Included in the Total column.

APPENDIX J
NAVY ENLISTED CLASSIFICATIONS TABLES
(Continued)

Table J-6.
List of Units/ Organization
Whose Personnel Received Zero Dose.

TABLE J-6D. - Miscellaneous Observer/Participant.

UNIT/ORGANIZATION	TOTAL PERSONNEL	NO. W/O RECORDS*
AEC ACTIVITIES		
NY Operations Office	1 civ	0
Santa Fe Operations Office	1 civ	0
Wash., D.C. Operations Office	2 civ	0
Los Alamos Scientific Lab	1 civ	0
UC Rad Lab Livermore	3 civ	0
OTHER RESEARCH ORG.		
APL, Univ. of Wash.	1 civ	0
William Miller Inst.	1 civ	0
TOTAL MISC. OBSERVERS	26 mil + 23 civ	2
TOTAL ZERO DOSE UNITS	2345 mil + 113 civ = 2458	65 w/o records

* Included in the Total column.

APPENDIX K

GLOSSARY

K-1 TERMS

Alpha particles (radiation): The emission of alpha particles (helium nuclei) by a nucleus.

AN/PDR radiac: Army/Navy Portable Dose Rate radiac. The military specification for a portable radiac meter.

Base surge: A cloud which rolls outward from the bottom of the column produced by a subsurface explosion. For underwater bursts, the visible surge is, in effect, a cloud of liquid (water) droplets with the property of flowing almost as if it were a homogeneous fluid. After the water evaporates, an invisible base surge of small radioactive particles may persist.

Beta particles (radiation): Small charged particles of very small mass emitted spontaneously from the nuclei of certain radioactive elements (isotopes). Most of the direct fission products emit negative beta particles. Radioactive isotopes, which emit beta radiation, give off particles moving at high velocity (about 170,000 miles per second) equal to electrons in mass, but charged either positively (positrons) or negatively (negatrons).

Bolometer gear: An instrument that measures the energy of electromagnetic radiation in certain wavelength regions by utilizing the change in resistance of a thin conductor caused by the heating effect of the radiation.

Condensation cloud (or Wilson cloud): A mist or fog of minute water droplets which temporarily surrounds the fireball following a nuclear detonation in a comparatively humid atmosphere. The expansion of the air in the negative phase of the blast wave from the explosion results in a lowering of the temperature, so that condensation of water vapor, present in the air, occurs and a cloud forms. The cloud is soon dispelled when the pressure returns to normal and the air warms up again.

$t^{-1.2}$ Decay Law: Describes the standard decay of mixed fission products. It can be described as $R_t = R_1 t^{-1.2}$

Deep drogue: A sea anchor - a funnel or cone-shaped device towed behind a vessel; in this case, one towed deep beneath the surface. A drag, usually a canvas-covered conical frame, floating behind a vessel to prevent drifting or to maintain a heading into the wind.

Dosage control: Dose rate is the amount of radiation which an individual or material receives per unit of time. Through the use of film badges, the amount of radiation that an individual receives over a period of time can be measured and therefore controlled and, when necessary, personnel may be restricted from further participation in test programs.

Dose: A measure of the energy absorbed in tissue by the action of ionizing radiation on tissue. As used in radiation protection, definitive practice requires that the term be used in such combining forms as radiation dose, absorbed dose, whole body dose, and partial body dose.

Dosimeter: A device which measures the exposure to radiation over a period of time.

Enewetak: A Pacific test site, formerly spelled Eniwetok.

Fallout: The fallout to the earth's surface of particles contaminated with radioactive material from a radioactive cloud. The term is also applied in a collective sense to the contaminated particulate matter itself. The early (or local) fallout is defined, somewhat arbitrarily, as those particles which reach the earth within 24 hours after a nuclear explosion. The delayed (or worldwide) fallout consists of the smaller particles which ascend into the upper troposphere and into the stratosphere and are carried by the winds to all parts of the earth. The delayed fallout is brought to earth, mainly by rain and snow, over extended periods ranging from months to years.

Film badge: A compact packet, worn on the person, containing film emulsions which, with appropriate screening, development, and evaluation, indicate the dose of ionizing radiation to which the wearer was exposed.

Fireball: A luminous sphere of hot gases which forms a few microseconds after a nuclear explosion as the result of the surrounding medium absorbing energy emitted by the weapon.

Fixed Gamma Intensity-Time Recorders (GITR): Permanently mounted electronic systems employing ionization chambers to provide continous data of gamma intensity vs. time (so named to distinguish them from the portable radiac instruments).

Gamma rays (radiation): Electromagnetic radiations originating in atomic nuclei and accompanying many nuclear reactions. Gamma rays are generated from processes within the nucleus, such as fissioning, decaying processes, and interaction with particles.

H-hour: The time of day (e.g., 5:30 a.m.) at which a device is detonated.

Inversion Layer: Strata of the atmosphere where an inversion of the normal temperature gradient take place; the air increases in temperature with increasing altitude.

APPENDIX K

GLOSSARY
(Continued)

Ionization: A process by which a neutral atom or molecule loses or gains electrons, thereby acquiring a net charge and becoming an ion; may be caused by ionizing radiation such as alpha, beta, and gamma.

Ionizing radiation: Particles or photons that have sufficient energy to produce ionization directly in their passage through a substance. Particles that are capable of atomic interactions in which sufficient energy is released to produce ionization.

Kingpost-location: At the approximate location of the foremast on the YAGs.

Laminae: Thin plates, sheets, or, as used in this report, a description of the various submerged layers of seawater.

Neutron-induced activity: Radioactivity induced in an element due to absorption of neutrons. Neutron-induced radioactivity is usually found near the surface ground zero or surface zero of a nuclear air burst.

Nuclear depth charge: A projectile, using nuclear energy for its explosive charge, to be detonated underwater against submarine or other underwater targets.

Overpressure: The pressure in excess of the normal, atmospheric value usually associated with passage of a shock front.

Photomultiplier tube: A phototube with one or more dynodes between its photocathode and the output electrode; the electron stream from the photocathode is reflected off each dynode in turn, with secondary emission adding electrons to the stream at each reflection (also known as electron-multiplier phototube; photoelectric electron-multiplier tube; photomultiplier).

Plume (or column): A hollow cylinder of water and spray thrown up from an underwater burst of a nuclear weapon, through which the hot, high-pressure gases formed in the explosion are vented to the atmosphere.

Prompt radiation: Radiation emitted within a few tenths of a microsecond by a nuclear burst. It consists of gamma rays and fission neutrons.

Rad-Safe (radiological safety): By means of these operations, a unit attempts to prevent the occurrence of hazards to personnel and equipment resulting from ionizing radiation of all forms.

Reagents: Any substance used in a chemical reaction to detect, measure, examine, or produce other substances.

Roll-up phase: Activities associated with bringing an operation to a conclusion.

Sample assay: A physical determination of the components of a sample.

APPENDIX K

GLOSSARY
(Continued)

Scintillation counter: A device in which the scintillations (i.e., light flashes) produced in a fluorescent material by an ionizing radiation are detected and counted by a multiplier phototube and associated circuits. (Also known as scintillation detector; scintillometer.)

Shear: As used in this report, describes a deformation of a solid body in which a plane in the body is displaced, parallel to itself, relative to parallel planes in the body; quantitatively, it is displacement of any plane relative to a second plane, divided by the perpendicular distance between planes.

Shine: Reflecting or scattering of radiation up from the surface of the water or air.

Ship skin: The outer hull of a vessel.

Slick: The trace of an advancing shock seen on a calm water surface as a circle of dark water rapidly increasing in diameter.

Sonde: An electronic sensor towed behind a vessel.

Spectrochemical analysis: The chemical analysis of a mixture of substances, or of a complex substance, by a study of spectra.

Spray dome: The mound of water spray thrown up when a shock wave from an underwater nuclear burst reaches the surface.

SQUAW: Specially designed and constructed submarine targets.

Surface zero: The point on the land or ocean surface (as distinguished from ground zero) vertically below or above the center of the burst of a nuclear weapon.

Telemeter: The complete measuring, transmitting, and receiving apparatus for indicating or recording the value of a quantity at a distance.

Test array (Target array): For WIGWAM, it consisted of a fleet ocean tug, on a fixed course, towing a 30,000-foot cable on the surface with the zero barge, containing the nuclear device, attached at the other end. The nuclear device was suspended on a 2,000-foot cable below the zero barge. A variety of instrument vessels, targets, instruments, and sampling stations were attached at various points along both cables.

Thermocline: A temperature gradient (particularly in a body of water), especially one making a sharp change. A layer of water in a thermally stratified lake or other body of water separating an upper, warmer, lighter, oxygen-rich zone from a lower, colder, heavier, oxygen-poor zone. Specifically, a stratum in which temperature declines at least one degree centigrade with each meter increase in depth.

USNRDL RBI-12 Beta Probes: Instruments used to measure beta-radiation intensity near contaminated surfaces. These instruments were modified to provide an extra "hi-lo" range switch and overall physical strengthening of the instrument.

Zero barge: (YC 473, an open lighter) A barge to which an underwater nuclear device is attached. The device hangs from a cable suspended beneath the barge.

K-2 ACRONYMS

AD:	Type of aircraft (attack, propeller-driven, manufactured by Douglas)
AEC:	Atomic Energy Commission
AF:	Type of aircraft (Navy) (anti-submarine warfare, propeller-driven, manufactured by Grumman)
AFSWP:	Armed Forces Special Weapons Project
AGC:	Amphibious Force Flagship
ARF:	Armour Research Foundation
ARS:	Salvage Craft, Tender
ASR-7:	Attack Air Squadron
ATF:	Fleet Ocean Tug
AN:	Net-Laying Ship
AN/PDR:	Army/Navy/Portable Detector Radiac
AV:	Seaplane Tender
BEIR:	Biological Effects of Ionizing Radiation
BIRLS:	Beneficiary Identification Records Locator Subsystem
CDC:	Center for Disease Control
CINCPAC:	Commander in Chief, Pacific
CVL:	Small Aircraft Carrier
cw:	Closed Window

APPENDIX K

GLOSSARY
(Continued)

DASIAC:	DoD Nuclear Information and Analysis Center (formerly the Defense Atomic Support Information and Analysis Center)
DD:	Destroyer
DDR:	Radar Picket Destroyer
DNA:	Defense Nuclear Agency
DoD:	Department of Defense
DTMB:	David Taylor Model Basin
EG&G:	Edgerton, Germeshausen, and Grier
HE:	High Explosive
HRS:	Helicopter Recovery Squadron
JCS:	Joint Chiefs of Staff
JTF7:	Joint Task Force Seven
KT:	Kiloton
LASL:	Los Alamos Scientific Laboratory
LBNS:	Long Beach Naval Shipyard
LCM:	Landing Craft, Mechanized
LML:	Lookout Mountain Laboratory
LSD:	Landing Ship, Dock
LST:	Landing Ship, Tank
MATS:	Military Air Transport System
MPBB:	Maximum Permissible Body Burden
MPC:	Maximum Permissible Concentration
MPD:	Maximum Permissible Dose
MPE:	Maximum Permissible Exposure
MPL:	Maximum Permissible Limit

GLOSSARY
(Continued)

NAS: National Academy of Sciences

NAS: Naval Air Station

NEL: U.S. Naval Electronics Laboratory

NOL: U.S. Naval Ordnance Laboratory

NOSC : Naval Ocean Systems Center

NOTS: U.S. Naval Ordnance Test Station

NPRC: National Personnel Records Center

NRDL: U.S. Naval Radiological Defense Laboratory

NRL: U.S. Naval Research Laboratory

NTPR: Nuclear Test Personnel Review

NTS: Nevada Test Site

OTC: Officer in Tactical Command

OW: Open Window

PDT: Pacific Daylight Time

RB: Rubber Boat

RBE: Relative Biological Effectiveness

SC: Sandia Corporation

SIO: Scripps Institution of Oceanography

TAD: Tactical Air Direction

TATC: Tactical Air Traffic Control

TE: Task Element

TG: Task Group

TU: Task Unit

XLCM: Landing Craft, Mechanized

GLOSSARY
(Continued)

YAG:	Utility Ship (converted Liberty ship)
YC:	Utility Open Lighter (towed)
YFNB:	Instrumented barge - large covered lighter (non-self-propelled)

K-3 MEASUREMENTS

Ci/cm^3	curies per cubic centimeter
c/g	counts per gram
CPM	counts per minute
Ci	curie. A measure of the activity (rate of disintegration or decay) of a radioactive substance. One curie equals 3.7 by 10^{10} nuclear disintegrations per second, or 2.2 by 10^{12} per minute.
MCi	megacurie = one million curies. A fission yield of 10 megatons creates approximately 1 megacurie of strontium-90.
micron	unit of pressure equal to the pressure exerted by a column of mercury one micrometer high, having a density of 13.5951 grams per cubic centimeter, under the standard acceleration of gravity.
mR	milliroentgen = 10^{-3}R
μR	microroentgen = 10^{-6} R
mR/h	milliroentgen per hour
mrep/hr	milliroentgen/equivalent/physical per hour
pCi/cm^3	picocuries per cubic centimeter
psi	pounds per square inch
R	roentgen
rad	unit of absorbed dose, 1 rad = absorption of 100 ergs of energy in one gram of any medium.
rem	roentgen/equivalent/man. A unit of dose whose biological effect is equal to that of absorption of one roentgen of gamma radiation. The rem can be defined as rem = rad X RBE or rem = rad X (QF X DF).

GLOSSARY
(Continued)

rep	roentgen/equivalent/physical. A unit formerly used for similar purposes as the rad, but defined for any type of radiation in terms of the energy absorbed in biological tissue equivalent to that which is absorbed by one roentgen of gamma radiation. (One rep has had various definitions, ranging from 84 ergs per cubic centimeter to 93 ergs per gram of tissue.)

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ATTN: Librn

Free Public Library of Elizabeth
ATTN: Librn

Free Public Library
ATTN: Librn

Freeport Public Library
ATTN: Librn

Fresno Cty Free Library
ATTN: Librn

Gadsden Public Library
ATTN: Librn

Garden Public Library
ATTN: Librn

Gardner Webb College
ATTN: Docs Library

Gary Public Library
ATTN: Librn

Geauga Cty Public Library
ATTN: Librn

Georgetown University Library
ATTN: Gov Docs Room

Georgia Institute of Technology
ATTN: Librn

Georgia Southern College
ATTN: Librn

Georgia Southwestern College
ATTN: Dir of Libraries

Georgia State University Library
ATTN: Librn

OTHER (Continued)

University of Georgia
ATTN: Dir of Libraries (Reg)

Glassboro State College
ATTN: Librn

Gleeson Library
ATTN: Librn

Graceland College
ATTN: Librn

Grand Forks Public City-County Library
ATTN: Librn

Grand Rapids Public Library
ATTN: Dir of Lib

Greenville County Library
ATTN: Librn

Grinnell College Library
ATTN: Librn

Guam RFK Memorial University Library
ATTN: Fed Depository Coll

University of Guam
ATTN: Librn

Gustavus Adolphus College
ATTN: Librn

South Dakota University
ATTN: Librn

Hardin-Simmons University Library
ATTN: Librn

Hartford Public Library
ATTN: Librn

Harvard College Library
ATTN: Dir of Lib

Harvard College Library
ATTN: Serials Rec Div

University of Hawaii Library
ATTN: Gov Docs Coll

Hawaii State Library
ATTN: Fed Docs Unit

University of Hawaii at Monoa
ATTN: Dif of Libraries (Reg)

University of Hawaii
Hilo Campus Library
ATTN: Librn

Haydon Burns Library
ATTN: Librn

Hennepin County Library
ATTN: Gov Docs

Henry Ford Community College Library
ATTN: Librn

OTHER (Continued)

Herbert H. Lehman College
ATTN: Lib Docs Div

Hofstra University Library
ATTN: Docs Dept

Hollins College
ATTN: Librn

Hopkinsville Community College
ATTN: Librn

Wagner College
ATTN: Librn

University of Houston Library
ATTN: Docs Div

Houston Public Library
ATTN: Librn

Tulane University
ATTN: Docs Dept

Hoyt Public Library
ATTN: Librn

Humboldt State College Library
ATTN: Docs Dept

Huntington Park Library
ATTN: Librn

Hutchinson Public Library
ATTN: Librn

Idaho Public Library & Information Center
ATTN: Librn

Idaho State Library
ATTN: Librn

Idaho State University Library
ATTN: Docs Dept

University of Idaho
ATTN: Dir of Libraries (Reg)
ATTN: Docs Sec

University of Illinois Library
ATTN: Docs Sec

Illinois State Library (Reg)
ATTN: Gov Docs Br

Illinois University at Urbana-Champaign
ATTN: P. Watson Docs Lib

Illinois Valley Community College
ATTN: Library

Illinois State University
ATTN: Librn

Indiana State Library (Reg)
ATTN: Serial Sec

Indiana State University
ATTN: Docs Library

OTHER (Continued)

Indiana University Library
ATTN: Docs Dept

Indianapolis Marion County Public Library
ATTN: Social Science Div

Iowa State University Library
ATTN: Gov Docs Dept

Iowa University Library
ATTN: Gov Docs Dept

Butler University
ATTN: Librn

Isaac Delchdo College
ATTN: Librn

James Madison University
ATTN: Librn

Jefferson County Public Library
Lakewood Regional Library
ATTN: Librn

Jersey City State College
ATTN: F. A. Irwin Library Periodicals
Doc Sec

John Hopkins University
ATTN: Docs Library

La Roche College
ATTN: Librn

Johnson Free Public Library
ATTN: Librn

Kalamazoo Public Library
ATTN: Librn

Kansas City Public Library
ATTN: Docs Div

Kansas State Library
ATTN: Librn

Kansas State University Library
ATTN: Docs Dept

University of Kansas
ATTN: Dir of Library (Reg)

University of Texas
ATTN: Lyndon B. Johnson School of Public
Affairs Library

Maine Maritime Academy
ATTN: Librn

University of Maine
ATTN: Librn

OTHER (Continued)

Kent State University Library
ATTN: Docs Div

Kentucky Dept of Library & Archives
ATTN: Docs Sec

University of Kentucky
ATTN: Gov Pub Dept
ATTN: Dir of Lib (Reg)

Kenyon College Library
ATTN: Librn

Lake Forest College
ATTN: Librn

Lake Sumter Community College Library
ATTN: Librn

Lakeland Public Library
ATTN: Librn

Lancaster Regional Library
ATTN: Librn

Lawrence University
ATTN: Docs Dept

Brigham Young University
ATTN: Docs & Map Sec

Lewis University Library
ATTN: Librn

Library and Statutory Dist & Svc
2 cy ATTN: Librn

Earlham College
ATTN. Librn

Little Rock Public Library
ATTN: Librn

Long Beach Public Library
ATTN: Librn

Los Angeles Public Library
ATTN: Serials Div U.S. Docs

Louisiana State University
ATTN: Gov Doc Dept
ATTN: Dir of Libraries (Reg)

Louisville Free Public Library
ATTN: Librn

Louisville University Library
ATTN: Librn

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Manchester City Library
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Mankato State College
ATTN: Gov Pubs

University of Maine at Farmington
ATTN: Dir of Libraries

Marathon County Public Library
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Principia College
ATTN: Librn

University of Maryland
ATTN: McKeldin Library Docs Div

University of Maryland
ATTN: Librn

University of Massachusetts
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Maui Public Library
Kahului Branch
ATTN: Librn

McNeese State University
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Memphis & Shelby County Public Library &
Information Center
ATTN: Librn

Memphis & Shelby County Public Library &
Information Center
ATTN: Librn

Memphis State University
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Mercer University
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Mesa County Public Library
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Miami Dade Community College
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University of Miami Library
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Miami Public Library
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Michigan State Library
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Michigan State University Library
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Michigan Tech University
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University of Michigan
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Middlebury College Library
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Millersville State College
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State University of New York
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Milwaukee Public Library
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Minneapolis Public Library
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University of Minnesota
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Minot State College
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Mississippi State University
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University of Mississippi
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Missouri University at Kansas City General
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University of Missouri Library
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M.I.T. Libraries
ATTN: Librn

Mobile Public Library
ATTN: Gov Info Div

Midwestern University
ATTN: Librn

Montana State Library
ATTN: Librn

Montana State University Library
ATTN: Librn

University of Montana
ATTN: Dir of Libraries (Reg)

Montebello Library
ATTN: Librn

Morhead State College
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Mt Prospect Public Library
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Murray State University Library
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OTHER (Continued)

Nassau Library System
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Natrona County Public Library
ATTN: Librn

Nebraska Library Community
Nebraska Public Clearinghouse
ATTN: Librn

University of Nebraska at Omaha
ATTN: Univ Lib Docs

Nebraska Western College Library
ATTN: Librn

University of Nebraska
ATTN: Dir of Libraries (Reg)

University of Nebraska Library
ATTN: Acquisitions Dept

University of Nevada Library
ATTN: Gov Pubs Dept

University of Nevada at Las Vegas
ATTN: Dir of Libraries

New Hampshire University Library
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New Hanover County Public Library
ATTN: Librn

New Mexico State Library
ATTN: Librn

New Mexico State University
ATTN: Lib Docs Div

University of New Mexico
ATTN: Dir of Libraries (Reg)

University of New Orleans Library
ATTN: Gov Docs Div

New Orleans Public Library
ATTN: Librn

New York Public Library
ATTN: Librn

New York State Library
ATTN: Docs Control Cultural Ed Ctr

State University of New York at Stony Brook
ATTN: Main Lib Docs Sec

State University of New York Col Memorial Lib
at Cortland
ATTN: Librn

State University of New York
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North Texas State University Library
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OTHER (Continued)

State University of New York
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New York State University
ATTN: Docs Ctr

State University of New York
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New York University Library
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Newark Free Library
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Newark Public Library
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Niagara Falls Public Library
ATTN: Librn

Nicholls State University Library
ATTN: Docs Div

Nieves M. Flores Memorial Library
ATTN: Librn

Norfolk Public Library
ATTN: R. Parker

North Carolina Agricultural & Tech State
University
ATTN: Librn

University of North Carolina at Charlotte
ATTN: Atkins Lib Doc Dept

University Library of North Carolina at Greensboro
ATTN: Librn

University of North Carolina at Wilmington
ATTN: Librn

North Carolina Central University
ATTN: Librn

North Carolina State University
ATTN: Librn

University of North Carolina at Wilmington
ATTN: Librn

University of North Carolina
ATTN: BA SS Div Docs

North Dakota State University Library
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University of North Dakota
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University of North Dakota
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North Georgia College
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OTHER (Continued)

Northeast Missouri State Univeristy
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Northeastern Oklahoma State University
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Northeastern University
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Northern Arizona University Library
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Northern Illinois University
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Northern Michigan University
ATTN: Docs

Northern Montana College Library
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Northwestern Michigan College
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Northwestern State University
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Northwestern State University Library
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Northwestern University Library
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Norwalk Public Library
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Northeastern Illinois University
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University of Notre Dame
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Oakland Community College
ATTN: Librn

Oakland Public Library
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Oberlin College Library
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Ocean County College
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Ohio State Library
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Ohio State University
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Ohio University Library
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Oklahoma City University Library
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Oklahoma City University Library
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OTHER (Continued)

Oklahoma Department of Libraries
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Omaha Public Library Clark Branch
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Onondaga County Public Library
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University of Oregon
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Ouachita Baptist University
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Pan American University Library
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Passaic Public Library
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Queens College
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Pennsylvania State Library
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Pennsylvania State University
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University of Pennsylvania
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University of Denver
ATTN: Penrose Library

Peoria Public Library
ATTN: Business, Science & Tech Dept

Free Library of Philadelphia
ATTN: Gov Pubs Dept

Philipsburg Free Public Library
ATTN: Library

Phoenix Public Library
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University of Pittsburgh
ATTN: Docs Office, G8

Plainfield Public Library
ATTN: Librn

OTHER (Continued)

Popular Creek Public Library District
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Association of Portland Library
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Portland Public Library
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Portland State University Library
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Pratt Institute Library
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Louisiana Tech University
ATTN: Librn

Princeton University Library
ATTN: Docs Div

Providence College
ATTN: Librn

Providence Public Library
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Public Library Cincinnati & Hamilton County
ATTN: Librn

Public Library of Nashville and Davidson County
ATTN: Librn

University of Puerto Rico
ATTN: Doc & Maps Room

Purdue University Library
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Quinebaug Valley Community College
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Auburn University
ATTN: Microforms & Docs Dept

Rapid City Public Library
ATTN: Librn

Reading Public Library
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Reed College Library
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Augusta College
ATTN: Librn

University of Rhode Island Library
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University of Rhode Island
ATTN: Dir of Libraries

Rice University
ATTN: Dir of Libraries

Louisiana College
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University of Rochester Library
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University of Rutgers Camden Library
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State University of Rutgers
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Rutgers University
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Rutgers University Law Library
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Salem College Library
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Samford University
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San Antonio Public Library
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San Diego County Library
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San Diego Public Library
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San Diego State University Library
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San Francisco Public Library
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San Francisco State College
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Savannah Public & Effingham Liberty Regional Library
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Scranton Public Library
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Seattle Public Library
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OTHER (Continued)

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Shreve Memorial Library
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Sioux City Public Library
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Skidmore College
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Slippery Rock State College Library
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South Carolina State Library
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University of South Carolina
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University of South Carolina
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South Dakota School of Mines & Technical Library
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South Dakota State Library
ATTN: Fed Docs Dept

University of South Dakota
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South Florida University Library
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Southeast Missouri State University
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Southeastern Massachusetts University Library
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University of Southern Alabama
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Southern California University Library
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Southern Connecticut State College
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Southern Illinois University
ATTN: Librn

Southern Illinois University
ATTN: Docs Ctr

Southern Methodist University
ATTN: Librn

University of Southern Mississippi
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OTHER (Continued)

Southern Oregon College
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Southern University in New Orleans Library
ATTN: Librn

Southern Utah State College Library
ATTN: Docs Dept

Southwest Missouri State College
ATTN: Library

University of Southwestern Louisiana Libraries
ATTN: Librn

Southwestern University
ATTN: Librn

Spokane Public Library
ATTN: Ref Dept

Springfield City Library
ATTN: Docs Sec

St Bonaventure University
ATTN: Librn

St Johns River Junior College
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St Joseph Public Library
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St Lawrence University
ATTN: Librn

St Louis Public Library
ATTN: Librn

St Paul Public Library
ATTN: Librn

Stanford University Library
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State Historical Soc Library
ATTN: Docs Serials Sec

State Library of Massachusetts
ATTN: Librn

State University of New York
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Stetson University
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University of Steubenville
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Stockton & San Joaquin Public Library
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Stockton State College Library
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Albion College
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OTHER (Continued)

Superior Public Library
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Swarthmore College Library
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Syracuse University Library
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Tacoma Public Library
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Hillsborough County Public Library at Tampa
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Temple University
ATTN: Librn

Tennessee Technological University
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University of Tennessee
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College of Idaho
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Texas A & M University Library
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University of Texas at Arlington
ATTN: Library Docs

University of Texas at San Antonio
ATTN: Library

Texas Christian University
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Texas State Library
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Texas Tech University Library
ATTN: Gov Docs Dept

Texas University at Austin
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University of Toledo Library
ATTN: Librn

Toledo Public Library
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Torrance Civic Center Library
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Traverse City Public Library
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Trenton Free Public Library
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Trinity College Library
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Trinity University Library
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University of Tulsa
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UCLA Research Library
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Uniformed Services University of the Health Sciences
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University Libraries
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University of Maine at Oreno
ATTN: Librn

University of Northern Iowa
ATTN: Library

Upper Iowa College
ATTN: Docs Coll

Utah State University
ATTN: Librn

University of Utah
ATTN: Special Collections

University of Utah
ATTN: Dir of Library

Utica Public Library
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Valencia Library
ATTN: Librn

Valparaiso University
ATTN: Librn

Vanderbilt University Library
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University of Vermont
ATTN: Dir of Libraries

Virginia Commonwealth University
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Virginia Military Institute
ATTN: Librn

Virginia Polytechnic Institute Library
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Virginia State Library
ATTN: Serials Sec

University of Virginia
ATTN: Pub Docs

Volusia County Public Library
ATTN: Librn

OTHER (Continued)

Washington State Library
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Washington State University
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Washington University Libraries
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University of Washington
ATTN: Docs Div

Wayne State University Library
ATTN: Libn

Wayne State University Law Library
ATTN: Docs Dept

Weber State College Library
ATTN: Libn

Wesleyan University
ATTN: Docs Librn

West Chester State College
ATTN: Docs Dept

West Covina Library
ATTN: Librn

Univeristy of West Florida
ATTN: Librn

West Georgia College
ATTN: Librn

West Hills Community College
ATTN: Library

West Texas State University
ATTN: Library

West Virginia College of Grad Studies Library
ATTN: Librn

University of West Virginia
ATTN: Dir of Libraries (Reg)

Westerly Public Library
ATTN: Librn

Western Carolina University
ATTN: Librn

Western Illinois University Library
ATTN: Librn

Western Washington University
ATTN: Librn

Western Wyoming Community College Library
ATTN: Librn

Westmoreland City Community College
ATTN: Learning Resource Ctr

OTHER (Continued)

Whitman College
ATTN: Librn

Wichita State University Library
ATTN: Librn

Williams & Mary College
ATTN: Docs Dept

Emporia Kansas State College
ATTN: Gov Docs Div

William College Library
ATTN: Librn

Willimantic Public Library
ATTN: Librn

Winthrop College
ATTN: Docs Dept

University of Wisconsin at Whitewater
ATTN: Gov Docs Lib

University of Wisconsin at Milwaukee
ATTN: Lib Docs

University of Wisconsin at Oshkosh
ATTN: Librn

University of Wisconsin at Platteville
ATTN: Doc Unit Lib

University of Wisconsin at Stevens Point
ATTN: Docs Sec

University of Wisconsin
ATTN: Gov Pubs Dept

University of Wisconsin
ATTN: Acquisitions Dept

Worcester Public Library
ATTN: Librn

Wright State University Library
ATTN: Gov Docs Librn

Wyoming State Library
ATTN: Librn

University of Wyoming
ATTN: Docs Div

Yale University
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Yeshiva University
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Yuma City County Library
ATTN: Librn

Simon Schwob Mem Lib, Columbus Col
ATTN: Librn

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