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Record Number: 203

File Name (TITLE): Underwater Pressure Measurements in the Lagoon

Document Number (ID): WT-605

DATE: 11/1952

Previous Location (FROM): CIC

AUTHOR: JTF 132

Addditional Information:

OrMIbox: 13

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Operation IVY

PACIFIC PROVING GROUNDS

November 1952

Project 6.7o

UNDERWATER PRESSURE MEASUREMENTS IN THE LAGOON

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Report to the Scientific Director

UNDERWATER PRESSURE MEASUREMENTS IN THE LAGOON

By

G. W. Rollosson

Sandia Corporation
Albuquerque, New Mexico
April 1953

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ABSTRACT

On Mike shot of Operation Ivy measurement of underwater pressures was attempted at four locations near the floor of the lagoon. Gauges were installed at distances ranging from approximately 5700 to 112,000 ft from ground zero and about 1 mile from the reef. The single usable record showed sharp pressure spikes at 0.3 and 0.6 sec after zero time. Although the later spike corresponded with the time of arrival of the air shock at the surface of the lagoon above the gauge, no satisfactory explanation for the first spike has been found. Because two of the four gauges used were apparently faulty in their operation and the recorder to which a third was connected failed to start at all, it was impossible to draw any conclusions regarding the nature or magnitude of the underwater shock.

ACKNOWLEDGMENTS

Plans for the underwater pressure measurements described in this report were executed by members of the Burst Studies Division (5111) of the Weapons Effects Department of Sandia Corporation. Field measurements and installation of the instrumentation were ably carried out by personnel of the Pacific Proving Ground Division (5233) of the Proving Ground Department. A list of participating personnel appears as the appendix to this report.

Special thanks must be given to Miss Sally Langenstein for her assistance in the preparation of the manuscript.

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UNDERWATER PRESSURE MEASUREMENTS IN THE LAGOON

1 PURPOSE AND SCOPE

Pressures produced by the underwater shock from surface bursts of atomic weapons are of particular interest because of their possible damaging effect on underwater structures such as submarine pens, boat hulls, pier foundations, and dams. In fact, a surface burst over water might do a maximum of damage because it is capable of destroying underwater and surface targets simultaneously. It is possible also that, for the same quantity of nuclear material expended, a surface burst with its much greater yield might produce more underwater damage than an underwater penetrating (gun-type) weapon with its low yield.*

Since data have been taken[1] on the underwater shock from an atomic explosion under water in a shallow lagoon, it was considered highly desirable to obtain similar information on the underwater shock from a surface burst under analogous circumstances. Thus Mike shot of Operation Ivy seemed to present an unprecedented opportunity to make measurements of this type even though Mike shot was to be burst on the surface of an island rather than on the water surface. It was recognized, of course, that any energy going into water shock would not enter the water directly but would be transmitted through the soil to the water. Consequently some reflection would be anticipated at the soil-water boundary. Nevertheless it was believed that enough information was forthcoming to make it worth while to undertake a small program of underwater shock pressure instrumentation on the lagoon side of the shot island. Because of its planned recording facilities on nearby islands, the Sandia Laboratory was asked to undertake these measurements.

2 INSTRUMENTATION

Underwater pressure gauges[2] were placed at four locations near the floor of the lagoon, approximately 100 ft below the surface. Distances from ground zero ranged from 5698 to 112,232 ft, and the distance from the edge of the reef forming the lagoon was approximately 1 mile. Detailed information regarding placement of the gauges is presented in Fig. 1 and Table 1.

* Clearly an underwater burst of an implosion-type weapon would be far more effective under water than at the surface.

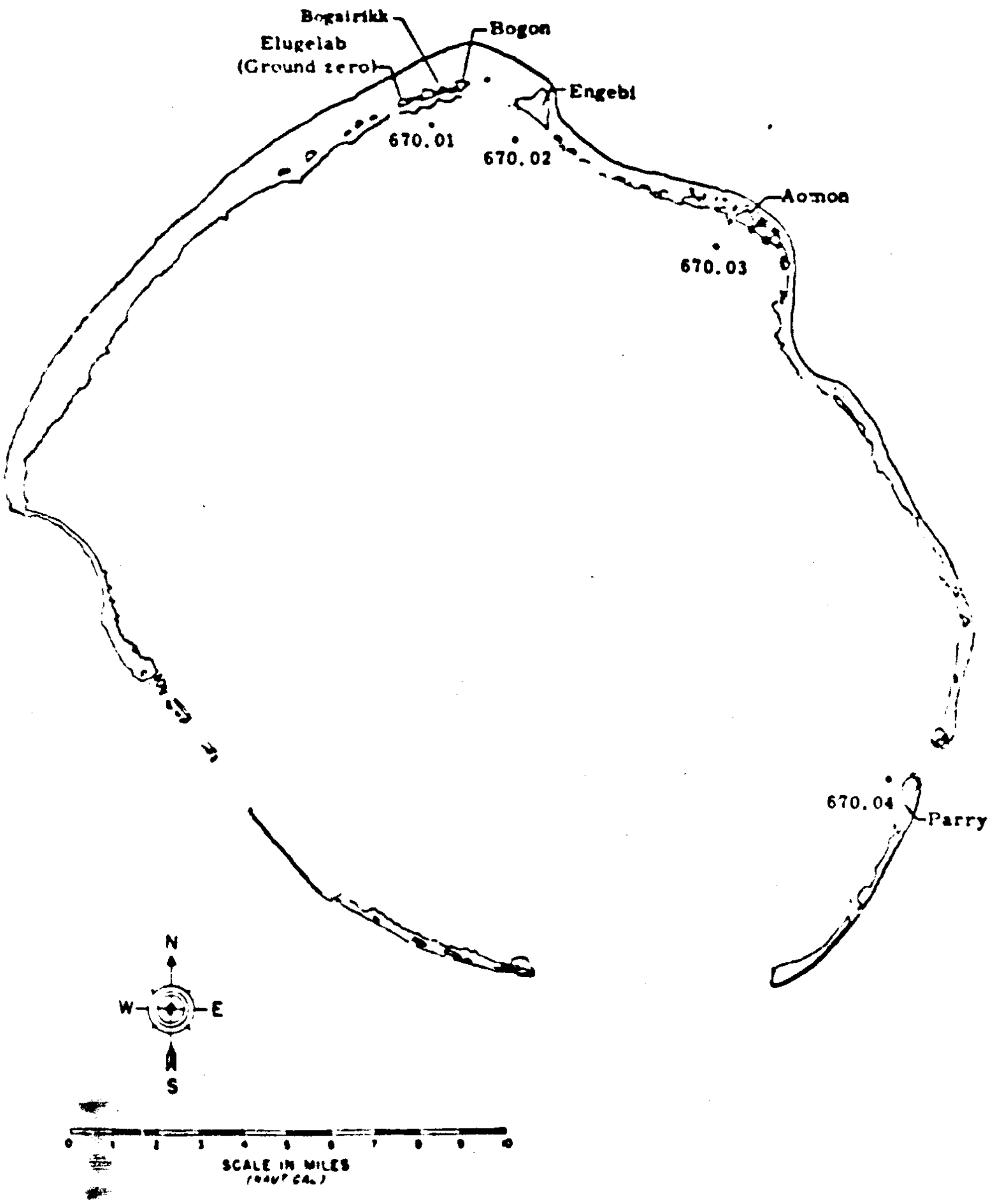

Fig. 1 — Layout of blast line for underwater pressure measurements.

Table 1 — LOCATIONS OF UNDERWATER GAUGES

Island*	Station No.	Distance from ground zero, ft	Approximate depth, ft	Set range, psi	Shelter No. and recorder
Bogairikk	670.01	5,698	100	3600	600(B)
Engebi	670.02	15,940	80	750	601(B)
Aomon	670.03	46,720	90	100	604(B)
Parry	670.04	112,232	100	22	606(A)

*Actually these installations were in the lagoon near these islands.

Set ranges for these gauges were scaled from the results of underwater shock pressure measurements on the underwater explosion at Bikini,[1] on the assumption that the fraction of the total energy going into underwater shock would be half as great from a surface burst as from an underwater burst. Thus the distances at which given underwater pressure levels were observed on the Bikini shot were scaled by means of the cube root scaling law to a yield of 2.5 Mt (half the predicted yield of 5 Mt). Whereas the assumption of half the yield going into underwater shock may be quite valid for a burst on the surface of the water, this fraction was probably too great in this particular instance because the shock energy had first to be transmitted through the soil of the shot island and then across the soil-water interface before it was translated into underwater shock energy. Also, no attempt was made to estimate the effects of reflection from the floor of the lagoon or of nonlinear cutoff of reflection from the surface of the water.

The gauges used (Fig. 2) were manufactured by the Wiancko Engineering Company (type 3PH90B) and were similar in operation to the air pressure gauges used by Sandia Laboratory on a number of operations.[3] A complete description of these gauges and of the Ampex recording system used in conjunction with them is presented by the Field Test Organization of Sandia Corporation in a special operational report.[2] The gauges were mounted on a pylon (Fig. 3) which suspended them about 10 ft off the floor of the lagoon.

3 RESULTS

Of the four recorders to which the underwater gauges were connected, one failed to start, and consequently no record was obtained for the gauge at Station 670.03. Only one of the remaining three magnetic tapes, that for the gauge at Station 670.01, appears to have recorded any signal from the gauge. Originally nonreceipt of signals from the gauges at Stations 670.02 and 670.04 was thought to have been attributable either to the low magnitude of the pressure pulses received or to a duration so short that the gauges failed to deflect.

Examination of two gauges that were recovered, however, revealed alternative explanations that were based upon possible malfunction of the gauge. It was found, for instance, that an air bubble is invariably trapped in the Bourdon tube during installation of the gauge unless a wetting agent is used. Since no wetting agent was used, it must be assumed that each of the gauges had an air bubble trapped in its Bourdon tube. Laboratory control tests indicate that this air bubble effectively increases the rise time of the gauge from approximately 0.5 to 2 msec at 15 psi, although this increase is probably a maximum. Such a condition would increase the requisite duration of the signal received, and it is probable that any pressure pulse having a duration less than 5 msec would not be "seen" by the gauge. A second source of gauge malfunction was the bursting of the air bubble in the back of the gauge; the air bubble in the back of the

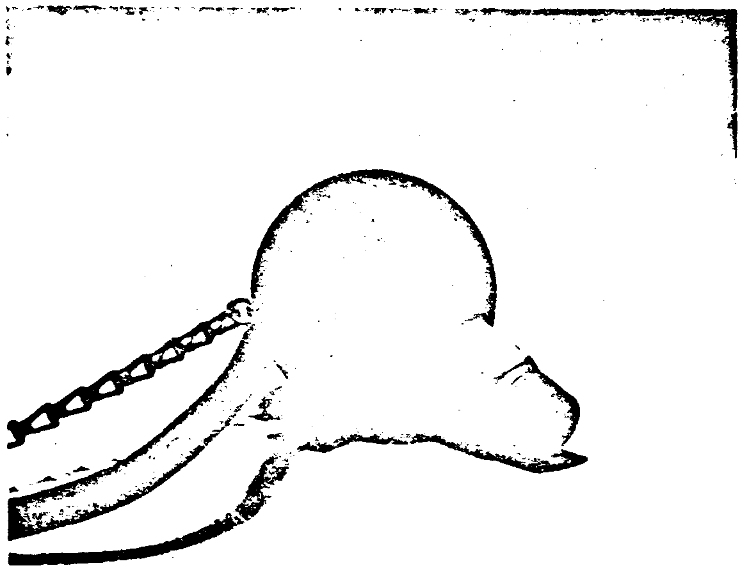

Fig. 2 — Underwater gauge (front view).

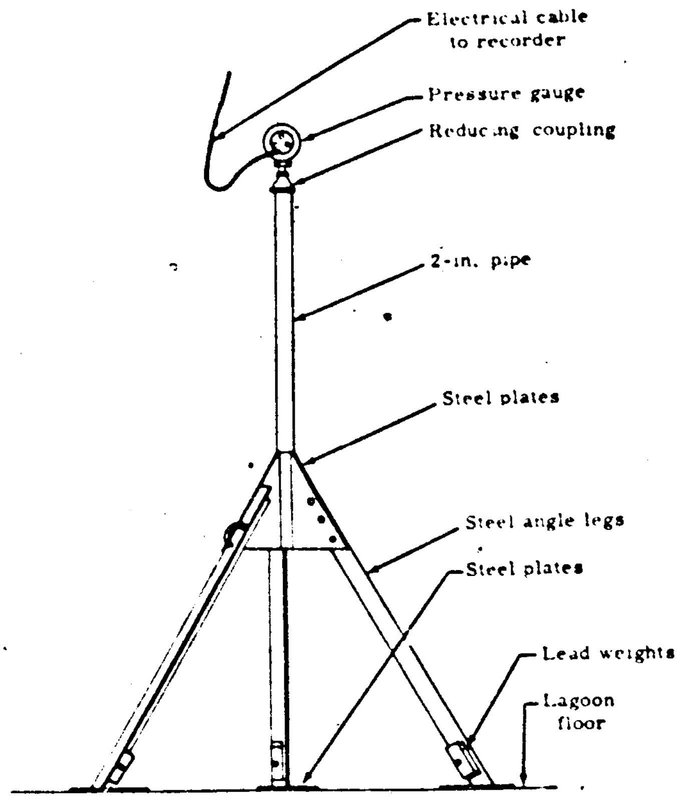

Fig. 3 — Sketch of gauge mount.

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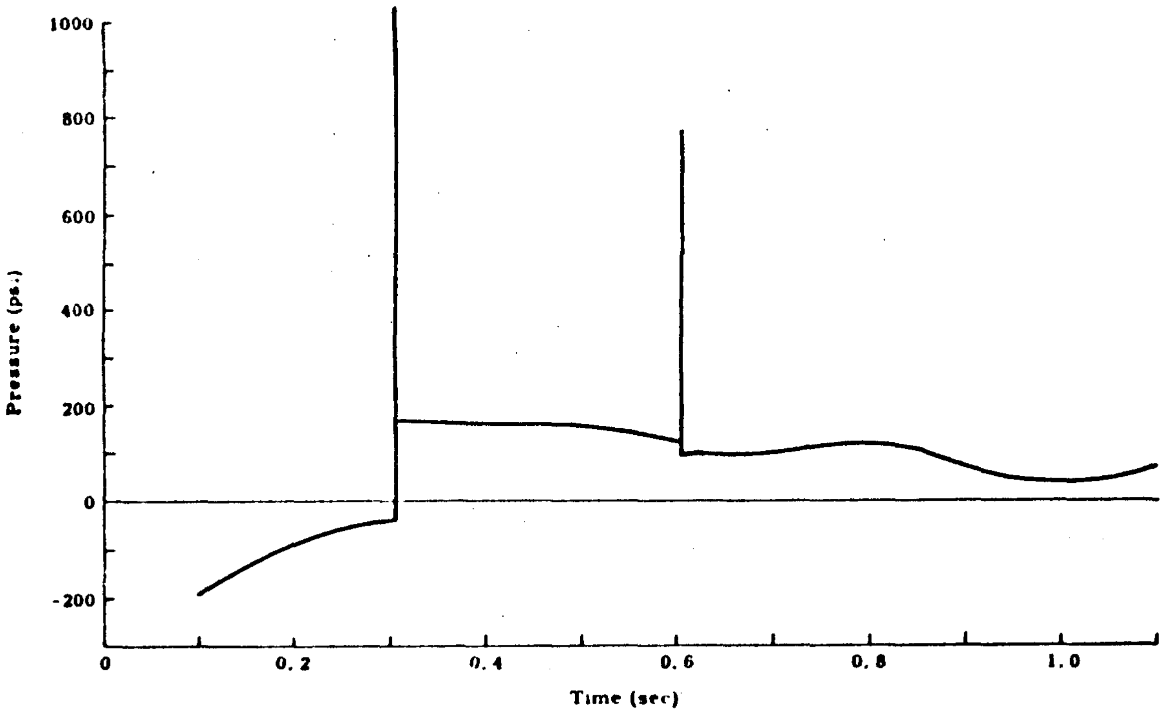

Fig. 4 — Pressure-time profile for gauge at Station 670.01.

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gauge at Station 670.02, one of the two recovered, had burst and had been absorbed by the oil, with the result that the back-leak time had been reduced essentially to zero and the gauge could not respond to any signal. Since there is no way of determining when this malfunction occurred, it must be assumed that the gauge was inoperative at the time of the shot. The gauge at Station 670.04 was not recovered; therefore it is not known whether it too was defective. The gauge at Station 670.01 was sealed at the back, however, and would have been unaffected by a burst air bubble.

It was from this gauge at Station 670.01, in fact, that the only usable record was received, and a pressure-time profile for this gauge is presented as Fig. 4. It is seen that the cables picked up a large electromagnetic transient signal at zero time which resulted in a zero set of the gauge at about −200 psi. While this set was in the process of recovering toward zero, the first signal was received at 0.305 sec. This signal, if it was a pressure signal, had a magnitude of 1035 psi and a duration of only 3 to 4 msec. The second signal, provided again that it was a pressure signal, was received at 0.604 sec and reached a peak pressure of 771 psi.

Interpretation of these two signals is difficult because of their times of arrival and extremely short durations. First of all, it is difficult to understand how any energy could have been transmitted to a distance of 5698 ft in 0.305 sec. Calculations from the record of the air shock indicate that it had traveled only 4386 ft in the same length of time, and its speed at this point was 6720 ft/sec. For the water shock to have attained a distance of 5698 ft it would have had to travel at a speed greatly in excess of that of the air shock. Moreover, had it had a speed equal to that of the air shock, the underwater shock would have had to be of the order of 73,500 psi,[4] a magnitude which seems entirely at variance with the record obtained.

The second pip at 0.604 sec coincided in arrival time with the air shock at the same distance. However, the overpressure of the surface air shock at this distance was about 250 psi, whereas the signal recorded by the underwater gauge was 771 psi. Too, the length of the signal was rather short for it to have been an air-shock-induced water shock.

4 CONCLUSIONS AND RECOMMENDATIONS

No conclusions can be reached about the magnitude of the underwater shock from Mike shot in view of the confusing nature of the single record obtained from these measurements. It is suggested that considerable work be done to improve the reliability of the Wiancko underwater pressure gauge if its use on future measurements of this type is contemplated. It is understood that a more complete program of underwater pressure measurements is to be undertaken on Operation Castle.

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3. P. A. Northrop, Instrumentation for Structures Program, Greenhouse Report, Annex 3.4, Part I, WT-1.
4. R. H. Cole, "Underwater Explosions," Princeton University Press, Princeton, N. J., 1948.

APPENDIX

Personnel of the Sandia Corporation Field Test Organization, under the direction of G. A. Fowler, performed the field installation and calibration of the pressure gauges and auxiliary instrumentation for these measurements. H. E. Lenander of the Proving Ground Department served as Project Officer of Project 6.1. Other members of the Sandia personnel force were

R. S. Millican, Division Supervisor of the Pacific Proving Ground Division

J. H. Scott, Project Engineer

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Bolinger, N. C.	Minck, J. L.	Thompson, R. H.
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Covington, M. B., Jr.	Neil, B. D.	Valentine, J. W.
Csinnjinni, C.	Pritchett, R. E.	Wistor, J. W.
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Hampson, E. P.	Richardson, H. M.	Wood, E. E.
Landes, G. N.	Shannon, E. V.	Yearout, R. M.
List, D. B.	Smith, J. W., II	

The following military personnel were assigned temporarily to the Field Test Organization for assistance on Operation Ivy:

Bonham, W. D.	Greenleaf, D. E.	Meinert, R. E.
Daniel, V. H., Jr.	Kelso, C. J.	Payne, W. C.
Gobble, D. E.	Korbe, A. J.	Vaughn, J. F.
Green, J. R.	Mandrell, W. L.	

E. F. Cox, M. Cowan, Jr., and G. W. Rollosson of the Weapons Effects Department of Sandia Corporation participated in the field operations. Cox also served as Co-Director, with F. Porzel, Los Alamos Scientific Laboratory, of Scientific Program 6 of Operation Ivy. Under his direction the following personnel from the Weapons Effects Department assisted in the analysis of the data obtained on these measurements:

M. Cowan, Jr.	G. W. Rollosson
B. F. Murphey	J. D. Shreve, Jr.

All data were reduced by the Mathematical Services Division, 5242, of Sandia Corporation.

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Commanding General, Air Materiel Command, Wright-Patterson AFB, Dayton, Ohio ATTN: MCAIDS	160-161
Commanding General, Air Training Command, Scott AFB, Belleville, Ill.	162-163
Commanding General, Air Research and Development Command, P. O. Box 1395, Baltimore, Md. ATTN: RDDN	164-166
Commanding General, Air Proving Grounds Command, Eglin AFB, Fla. ATTN: AG/TRB	167
Commanding General, Air University, Maxwell AFB, Ala.	168-169
Commandant, Air Command and Staff School, Maxwell AFB, Ala.	170-171
Commandant, Air Force School of Aviation Medicine, Randolph AFB, Tex.	172-173
Commanding General, Wright Air Development Center, Wright-Patterson AFB, Dayton, Ohio ATTN: WCOESP	174-179
Commanding General, Air Force Cambridge Research Center, 230 Albany Street, Cambridge 39, Mass ATTN: Atomic Warfare Directorate	180
Commanding General, Air Force Cambridge Research Center, 230 Albany Street, Cambridge 39, Mass. ATTN: CRTSL-2	181
Commanding General, Air Force Special Weapons Center, Kirtland AFB, N. Mex. ATTN: Chief, Technical Library Branch	182-184
Commandant, USAF Institute of Technology, Wright-Patterson AFB, Dayton, Ohio ATTN: Resident College	185
Commanding General, Lowry AFB, Denver, Colo. ATTN: Dept. of Armament Training	186-190
Commanding General, 1009th Special Weapons Squadron, Tempo "T," 14th and Constitution Sts., N. W., Washington 25, D. C.	191-193
The RAND Corporation, 1700 Main St., Santa Monica, Calif. ATTN: Nuclear Energy Division	194-195

OTHER DEPARTMENT OF DEFENSE ACTIVITIES

Executive Secretary, Joint Chiefs of Staff, Washington 25, D. C.	196
Director, Weapons Systems Evaluation Group, OSD, Rm 2E1006, Pentagon, Washington 25, D. C	197
Asst. for Civil Defense, OSD, Washington 25, D. C.	198
Chairman, Armed Services Explosives Safety Board, D/D, Rm 2403, Barton Hall, Washington 25, D. C	199
Chairman, Research and Development Board, D/D, Washington 25, D. C. ATTN: Technical Library	200
Executive Secretary, Military Liaison Committee, P. O. Box 1814, Washington 25, D. C.	201
Commandant, National War College, Washington 25, D. C. ATTN: Classified Records Section, Library	202

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Commandant, Armed Forces Staff College, Norfolk 11, Va. ATTN: Secretary	203
Commanding General, Field Command, Armed Forces Special Weapons Project, P. O. Box 5100, Albuquerque, N. Mex.	204 - 209
Chief, Armed Forces Special Weapons Project, P. O. Box 2610, Washington 13, D. C.	210 - 218

ATOMIC ENERGY COMMISSION ACTIVITIES

U. S. Atomic Energy Commission, Classified Document Room, 1901 Constitution Ave., Washington 25, D. C. ATTN: Mrs. J. M. O'Leary (for DMA)	219 - 221
Los Alamos Scientific Laboratory, Report Library, P. O. Box 1663, Los Alamos, N. Mex. ATTN: Helen Redman	222 - 231
Sandia Corporation, Classified Document Division, Sandia Base, Albuquerque, N. Mex. ATTN: Martin Lucero	232 - 251
University of California Radiation Laboratory, P. O. Box 808, Livermore, Calif. ATTN: Margaret Folden	252 - 253
Special Projects Branch, Technical Information Service, Oak Ridge	254
Technical Information Service, Oak Ridge (surplus)	255 - 280

AEC, Oak Ridge, Tenn., A11548

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