Chapter

9

Historical Record: "The Port Chicago, California, Ship Explosion of 17 July 1944"

The many hundreds of pages of previously classified Government records that report the circumstances and physical manifestations of the Port Chicago explosion are composed, in the greater part, of extensively detailed data obtained by measurement of the actual, physical effects of the Port Chicago explosion. Those data and analyses of those data were necessary to confirm the Manhattan Project's mathematically modeled, theoretical forecasts of the destructive effects that would result from the use of atomic bombs designed to accomplish military objectives, tactical and strategic.

Most of the comprehensive data and analyses of those data that are available in Government Port Chicago explosion records are extraneous to the purpose of this book and will not be considered. Sections of available Port Chicago explosion records, for example, that precisely detail and mathematically dissect the "Percentage of plaster damage to total houses damaged" and the "Frequency distribution of number of structural members broken by buildings, area" would be neither instructive nor interesting to a general readership.

Information summaries that exist in the Port Chicago explosion records do, however, expertly condense many pages of detailed data and data analyses; those summaries are so well written that they provide excellent, succinct statements of information appropriate to the general reader's interest, which is to comprehend the artifacts of the explosion

and to arrive at a determination of its cause. Information summaries and germane portions of the text of Port Chicago explosion records presented in this and subsequent chapters will be exactly transcribed, except obvious typographical errors in an original record will be corrected. For example, "testimoney" will be correctly spelled.

"The Port Chicago, California, Ship Explosion of 17 July 1944." Army-Navy Explosives Safety Board Technical Paper No. 6. Washington, D.C., 1948.

This record is approximately 165 pages including text, maps, charts, tables and diagrams; the record was declassified 29 March 1957 by Commander H.E. Jennings, USN, for the Armed Services Explosives Safety Board (ASESB), now the Department of Defense Explosives Safety Board (DDESB). Many of the maps, charts, tables and diagrams in available copies of this record are so poorly copied that they are only partially legible. I obtained one copy of this record in 1981. This record was re-classified, 1982, to be available only to "qualified" Department of Defense contractors. By the courtesy of Dan Tikalsky, retired Concord Naval Weapons Station Public Affairs Officer, one copy was deposited, 1992, with the Office of the Regional Historian, U.S. National Park Service Western Regional Office, San Francisco. That office erroneously credits Commander H.E. Jennings as the author of this report. Colonel D.C. Hall, president of the Army-Navy Explosives Safety Board, in his foreword to the report, credits Army-Navy Explosives Safety Board staff member Dr. Ralph Ilsley with "the analysis and correlation of the data and the preparation of this report." Commander Jennings approved the 1957 declassification of this report but had no role in the 1948 report preparation or writing.

Extracts from:

"The Port Chicago, California, Ship Explosion of 17 July 1944."

ABSTRACT.

The explosions on 17 July 1944 at Port Chicago, California, of about 3,500,000 pounds of explosives in railroad cars on the pier and in the holds of a ship resulted in the death of 320 people, injuries to 390, and property damage estimated to be $13,000,000. The 10,000 claims submitted to the U.S. Navy Board of Investigation and the voluminous testimony of the U.S. Navy Court of Inquiry have been reviewed and utilized so as to present a factual narrative of important aspects of the explosion such as types and magnitude of injuries, zones of major damage, types of damage to houses and contents, magnitude of damage in relation to direction of structure to blast wave, damage by the water wave, magnitude and type of missiles, extent and depth of true crater, the 'false' crater, decrease in magnitude and types of damage with greater distance from the pier and relation of formulas of limiting distance of structural damage – British and American – with actual facts.

The damage relationships by types, magnitude, direction and distance from the pier are recorded in the report by description, charts, tables, maps and in many cases by the determination of a formula for the fitted curve for the amount of damage per locality.

The U.S. Naval Magazine, Port Chicago, California.

The location of Port Chicago as a Naval Magazine was chosen with extreme care, in a sparsely settled area, with deep tidewater along the northern boundary and with two transcontinental railways on the southern boundary. The ship loading pier was built to transfer am-

munition from railroad cars directly into deepwater ships. After several modifications the pier was completed in May, 1944, so that two ships could be handled simultaneously on opposite sides of the pier. An additional facility, consisting of a marginal pier with two ship loading berths in tandem, was in later stages of completion at the time of the explosion. The Naval Magazine of Port Chicago was primarily a transfer facility and the magazine's responsibility started with the receipt of loaded railway cars and ended when the cargo had been stowed in ships or barges.

The completed pier had three tracks, and at each edge a loading platform 18 feet wide and car floor high. Railway cars were spotted opposite the holds into which the material was to be loaded. The center track was used primarily for switching, but occasionally railway cars were spotted on the center track opposite a hatch and the material handled through the car just emptied. The physical limitations of the pier prevented unnecessary concentration of ammunition on the pier.

The material was taken out of the cars, placed on the platform under the ship's booms, hoisted on board, and stowed in the holds. The ships were loaded on a three-shift schedule to meet the required ammunition shipments. In collaboration with Port Chicago and Service Force, the Port Director prepared a loading plan for each ship and, as agents for the operators of the ship, submitted it to the Captain of the Port for a loading permit. The separation of various classes of explosives and the stowage of the same in merchant ships were determined according to regulations in effect on 17 July 1944; namely, "Regulations Governing Transportation of Military Explosives on Board Vessels During present Emergency." (U.S. Coast Guard, 1 October 1943.)

A senior loading officer was in charge of all loading and qualified junior loading officers were on the pier during all periods of activity.

Land security from unauthorized intrusion was maintained by a Marine Sentry System. Waterfront security was maintained by Coast Guard patrol boats. Prevention and control of fires was planned by adequate fire apparatus on land, fire watch, pumpers on loading pier and a Coast Guard fire barge secured at the end of the ship loading pier. Smoking

was prohibited except in specified areas. Automobiles and trucks were not permitted on the pier beyond the pier office.

*Factual Details Immediately Prior to the Explosion.**

(*Throughout most of the report, the singular form will be used although two distinct explosions were verified and the possibility of three indicated.)

Ships and Pier.

The S.S. Quinault Victory, a new vessel of the Victory type, was moored starboard side to, headed east at the outboard berth. Port Chicago Naval Magazine personnel were rigging the ship for loading and all hatches except No. 5 were about ready to load at the time of the explosion. Dunnage and loaded cars of ammunition and bombs were spotted on the pier beside the Quinault Victory in preparation for the initial loading and stowage at midnight.

The S.S. E. A. Bryan, a new vessel of the Liberty type, had completed one trans-Pacific trip and after undergoing voyage repairs had been assigned to Port Chicago for a cargo of ammunition and bombs. It moored on 13 July 1944 and thereafter loaded continuously day and night until the explosion of 17 July 1944 at about 10:19 P.M. Pacific War Time. At the time of the explosion there were approximately 4,600 tons of ammunition and bombs, containing 1780 tons of high explosives and 200 tons of smokeless powder, in or being loaded in the various holds. The E. A. Bryan was moored starboard side to, headed west at the inboard berth. Sixteen railroad cars, loaded with various types of ammunition and bombs, were spotted on the pier. The cars had approximately 430 tons of cargo containing 150 tons of high explosives and 10 tons of smokeless powder.

[Note. The "Abstract" of this Army-Navy Explosives Safety Board record states that "about 3,500,000 pounds of explosives in railroad cars on the pier and in the holds" of the *E. A. Bryan* were available to the Port Chicago explosion. "Explosives" as used here means the

TNT charge weight of the munitions on the pier and in the holds of the *E. A. Bryan;* 3,500,000 pounds equates to 1,750 tons of TNT.

[In Chapter 8 we established that a TNT charge weight of 1,577 tons was on board the *E. A. Bryan.* The 150 tons of high explosive (TNT) in cars on the shiploading pier mentioned in the record paragraph above, when added to the 1,577 tons of TNT aboard the *E. A. Bryan,* gives a total TNT charge weight for the Port Chicago explosion of 1,727 tons or 3,454,000 pounds of TNT. The difference between 3,454,000 and 3,500,000 pounds, which latter number is cited in the "Abstract," is 46,000 pounds or 23 tons. In the context of the Port Chicago explosion a difference of 23 tons TNT charge weight is insignificant—"about 3,500,000 pounds" were available to the explosion.

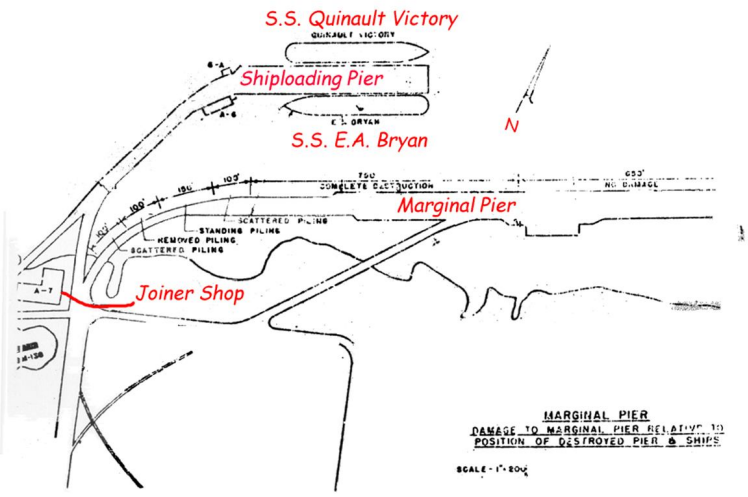
[However, in a later section of this record the National Defense Research Committee (NDRC) is reported to have used 4,272,000 pounds (2,136 tons) of TNT to represent the energy of the Port Chicago explosion. The 409 tons difference between 1,727 and 2,136 tons is a significant difference. An additional 409 tons charge weight cannot be accounted by the total high explosive munitions documented to have been in railroad cars on the pier and on board the *E. A. Bryan.* An augment of 409 tons of explosive energy to the Port Chicago explosion can, however, be accounted by the "few hundred tons of TNT equivalent" that Atomic Bomb Military Policy Committee member James Conant predicted on 4 July 1944 could be the energy produced by the anticipated proof of the Mark II atomic bomb.]

The assistant to the Senior Loading Officer had started an inspection of the pier at 9:30 P.M. and left four or five minutes before the explosion at 10:19 P.M. According to him, the Quinault Victory had not started loading but the E. A. Bryan was loading as follows: Incendiary bombs in No. 1 hold; depth bombs in No. 2 hold; tail vanes in No. 3 hold; fragmentation cluster-bombs in No. 4 hold; and 40 mm. [ammunition] in No. 5 hold. He did not notice anything unusual as to the loading methods and no unusual problems were reported to him. The night was dark, clear, and cool; the

wind was force 1 to 2 from the southwest, and the tide had been flooding for one hour.

Immediate Vicinity of the Pier.

Within about a mile of the pier were situated the administrative, storage, service, and barracks buildings of the Naval Magazine. Except for the usual personnel on duty the greater part of the remaining personnel had retired for the night. The moving picture show in the new recreation building had been attended by about 700 personnel but had let out about 32 minutes before the explosion. Three employees of a construction company for the marginal pier were working overtime in the company office which was built on shore immediately south of the two piers. At the approach end of the main pier was the joiner shop, and working therein were five civilians and a Marine private. In the revetment area, filled with about 140 loaded cars of ammunition and bombs, an engine crew was shifting cars for the directed needs of the pier transportation officer. Marine guards, some with trained dogs, were patrolling various posts, one of which included the approach end of the loading pier outward to the main bend.



Diagram, Port Chicago Naval Magazine, ships and piers

In the channel, an empty oil tanker had approached a point – 1,200 feet – approximately midway between the loading pier and a lighthouse situated directly across the channel on Roe Island. A Coast Guard patrol boat had just passed the loading pier a few minutes before the explosion. A tug with a barge in tow was about 2,800 feet to the northwest of the pier.

At Port Chicago station, a mile to the south of the pier, a passenger train of the Southern Pacific Railroad had just arrived at the station at the time of the explosion. A greater part of the people of the town of Port Chicago, one to two miles south of the pier, were either in bed or

were preparing to retire. In the theater with a seating capacity of 386 people, there were about 195 people watching the movies. A touring circus had a one-day engagement at Port Chicago and although the show was finished the "big top" had not been taken down and packed away.

In the air at 9,000 feet a C-49 cargo plane was flying from Oakland to Sacramento and the pilot and co-pilot estimated they were about one and one-half minutes away from the scene of the explosion or about four or five miles away at their rate of travel – 150 miles per hour. Another plane was flying at about 7,000 feet and was three miles away proceeding north.

The Explosions.

The interpretation of the recordings of seismographs in the general vicinity of San Francisco, California, although not conclusive, indicated that two explosions took place between 2218:47 and 2218:54½ Pacific War Time, 17 July 1944, and that the second was greater than the first. Witnesses described the first explosion as sharp and loud as contrasted with the second which was deeper and poorly defined. Furthermore, the first explosion appeared confined as it ascended in a column of boiling and billowing mass of burning gases with a mushrooming top. The outside was darker than the inside and showed flashes of orange, red, and variations of the same. The first flash was brilliant white changing later to yellow and reddish-orange as the column rapidly gained altitude. The second explosion was not confined and spread in all directions from the pier area as a center. The second explosion apparently culminated in the mass detonation of all remaining explosives, especially those of the E. A. Bryan.

The pilot of the plane, cruising at 9,000 feet and four to five miles away, described the explosion as a terrific white flash with a large smoke ring that spread out in a horizontal plane; within the terrific flash he recognized pieces of white hot metal as it mounted at least 500 feet higher than the elevation of the plane; only one was seen which lasted for ten to fifteen seconds. The pilot of the plane cruising at 7,000 feet and three miles away saw an original flash with its billowy flame

and pyrotechnics display. The column appeared to have reached an altitude at least 1,000 feet above the plane. (He believed the billowy mass reached its maximum height in about 15 seconds.) A few seconds after the original flash, the pilot said the plane received a terrific concussion as if it had been hit by something; however, on landing he could find only scratches under the wing surface and on the side of the fuselage.

The officer-in-charge of Roe Island Lighthouse, which is situated directly across the channel from the loading pier – 3,280 feet – described the first explosion as "shaking the lighthouse violently, smashing in all the windows and tossing furniture around." There was no evidence of fuel oil having been sprayed on Roe Island as a result of the water wave.

On the other hand, the Patrol Boat U.S. Y.P. Miahelo II, in the channel about 500 yards from the pier [Note. Should be 1,400 yards—4,200 feet], was heavily sprayed with fuel oil when the water wave broke over the boat. The combined effect of water, blast, and missile damage resulted in a "constructional loss" of the patrol boat.

An oil tanker, the M.S. Redline, was damaged severely by the blast wave, water wave, and missiles. The salvage value was estimated to be about twelve per cent of the actual replacement cost. Fisherman's channel lights Nos. 1 and 2 were destroyed and Suisun Bay lighted buoy No. 4 was struck by a missile and sank.

The buildings of the Naval Magazine were damaged extensively; sporadic damage to structural members of buildings was proven up to 13 miles – Suval [railroad] Station, California; plate glass was broken up to 35.5 miles – Petaluma, California; and a legitimate claim for plaster damage was reported at 48 miles – Calistoga, California.

Damages as a Result of the Explosions.

As a result of the explosions the following deaths were recorded:

Number Recorded & Identified	Number of Deaths	
17	202	enlisted personnel of loading crews of E.A. Bryan and Quinault Victory.
5	9	officers associated with loading division
1	67	officers and crew of both vessels.
0	30	officer – 1 – and enlisted men – 29 of armed guard of both vessels.
2	5	enlisted men of Coast Guard fireboat
1	1	Marine Sentry on approach end of pier.
1	3	Civil Service employees of train crew on pier
3	3	employees of construction company for new pier.
30	320	totals

A total of 81 bodies were recovered but only 30 bodies were identified.

Except for the Marine sentry walking his post on the approach end of the pier and the three employees of the construction company, all others killed must have been at the outer part of the pier in or about the E. A. Bryan, the Quinault Victory, and the fireboat. It was testified that the Marine sentry probably died from multiple wounds as a result of being struck by missiles. The three employees of the construction company, who were working in temporary offices on shore almost directly

south of the E. A. Bryan, likewise were killed probably by missiles. Although the joiner shop at the land edge of the pier entirely collapsed, the five persons therein at the time of the explosion escaped without major injuries.

Personnel and Civilian Injuries.

Twenty-five of the 30 men of the Navy Armed Guard crew of the *E.A. Bryan* killed in the explosion

Most of the injuries to civilians and naval personnel of the Naval Magazine were superficial, resulting from shattered glass from windows and doors. The total injured listed from all causes was 390 of which 237 were Navy; 6 Marine Corps; 4 Coast Guard; 5 Maritime Service; 25 Civil Service; and 113 civilians. . . . It is important to note that 54 per cent of all injuries were in the vicinity of the eyes.

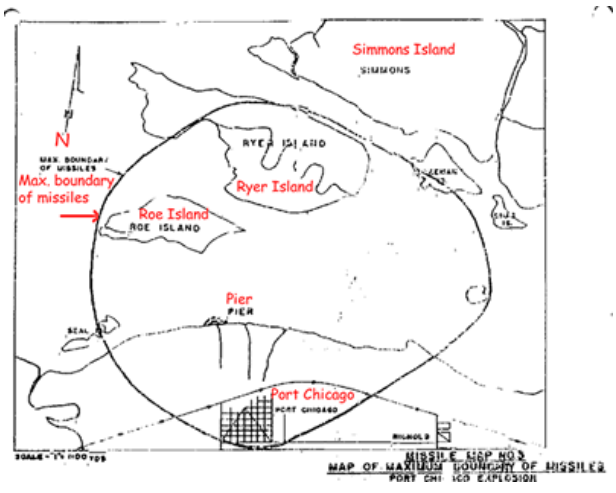
Property Damage.

The damages to property were estimated to be 12.5 millions of dollars. [Note. Government property damage, including destruction of the Government-owned *Quinault Victory* and *E. A. Bryan,* were estimated to be $9,892,034, which was 79 per cent of the total estimated damages to property.]

Loading Pier and Ships.

Except for 200 feet of the approach end, the loading pier was destroyed along with a diesel locomotive, 16 carloads of ammunition and bombs, and a utility building 100 x 26 x 14 feet which were on it. Many missiles, recognized as parts of the railroad cars, were found on Roe Island to the north and a few were found in the vicinity of the revetments to the south. The joiner building, situated on land close to the approach to the pier and at a distance of 1,000 feet from the center of the pier was demolished but three men working therein were rescued without serious injury. These men were the closest to the explosion that

survived. [Note: elsewhere, five men and one Marine are reported to have been in the joiner shop.] A Marine sentry walking his post on the approach end of pier was killed, probably by missiles.



Map of maximum boundary of missiles.

The Coast Guard fireboat at the end of the pier was destroyed and a diver was able to recognize the twisted remains by entangled fire hose. A body of one of the enlisted personnel was found in the wreckage.

The ships, E. A. Bryan and Quinault Victory, were destroyed and the former furnished the greater part of the steel missiles which showered the area. Large pieces, later identified as parts of the hull of the Quinault Victory, were found imbedded in the muddy bottom of the bay north of the pier. One piece of keel, 60 to 70 feet long with its propeller attached, was lying upside down and could be seen at low tide. The keel was creased and buckled in one place and was sheared at the end opposite the propeller. The hull showed a large hole about 15 to 20 feet from the propeller. Offshore, from the visible portion with propeller attached, was found a portion of the mast with bow headed downstream. The bow was cut off apparently at the bulkhead.

The position of those two large parts identified as originating from the Quinault Victory indicated that the stern had moved through an angle of 180 degrees whereas the bow had moved through and angle of less than 25 degrees.

Barracks and Administration Area.

In the barracks and administration area, situated immediately south of the revetment area, the long axis of most of the buildings was parallel to the direction of the blast wave. The most seriously damaged buildings were an old recreation building – about 94 per cent; the laundry

building – 81 per cent; the officers' lounge – 75 per cent; and the new recreation building – 73 per cent.

Nine barracks buildings, each two-story 42' x 150', with frame construction on concrete piers, wood floors, rustic siding and composition roofs, had the long axis about parallel to the direction of the blast wave. These buildings had damage of about 20 per cent of the cost of construction. The north wall of several barracks buildings were demolished by the pressure wave; the south walls were slightly damaged; wall panels were loosened; partitions were damaged; window glass was destroyed; sash and frames were damaged.

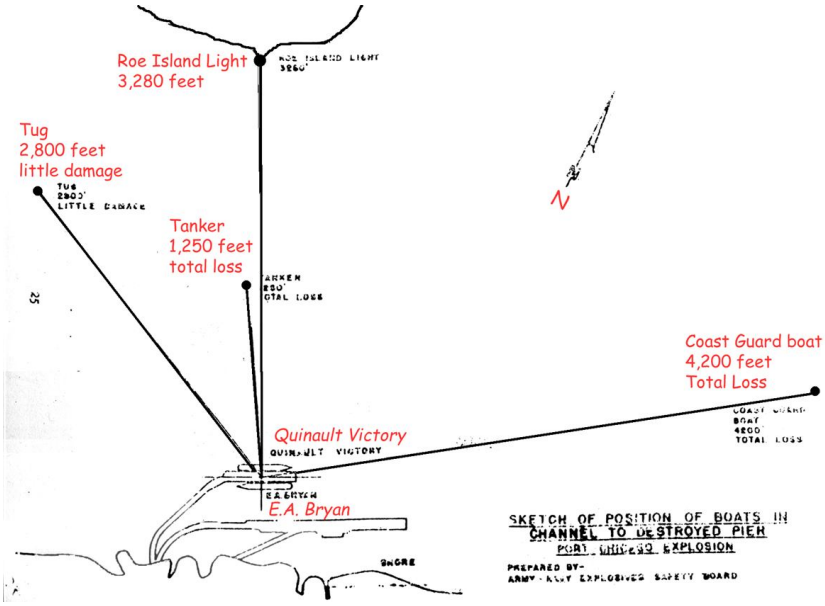
Waters Adjacent to the Naval Magazine.

The following ships were in the channel, within a mile of the loading pier, at the time of the explosion:

Name	Type	Distance from pier
M.S. Redline	Empty oil tanker of about 388 tons.	1,250 ft.
Governor MBM	Tugboat with barge loaded with bulk gasoline.	2,800 ft.
Y.P. Miahelo II	Coast Guard Patrol boat	4,200 ft.

The position of the boats to the pier at the time of the explosion is indicated by the sketch map on Page 25. The M.S. Redline sustained damage both from the blast wave and from missiles with some additional damage from the water wave. The superstructure was almost gone, all the tank tops were broken open, and the steel plates were bent, some even twisted and cut. The engine room was penetrated by a 14-inch projectile and another penetrated not only the top of the deck

house but also two bunks therein. The engine was knocked out so that it became necessary to tow the tanker to a wharf. After appraisal of the cost of repairs it was estimated that the M.S. Redline was 88 per cent damaged. Of the crew of eight, the chief engineer received a cut on the head and an injured shoulder; the pilot had a cut on the neck and a broken ankle; a seaman had a bruised head and glass in one eye; another seaman had a cut on one hand and a bruise on the other. Four members of the crew were uninjured.



Sketch of position of boats in channel to destroyed pier.

The Governor MBM, a tugboat towing a barge loaded with bulk gasoline, passed the loading pier shortly before the explosion. The tugboat carried a crew of three, one on the barge and two on the tugboat. The two men on the tugboat were knocked out temporarily but did not have any other injuries. The boat was shaken badly by the water wave as well as the blast wave. The boat began to leak shortly after the explosion but by frequent pumping it was possible to keep her in service for several months after the explosion.

The patrol boat Y.P. Miahelo II, at the time of the explosion, was headed away but in the direct line with the pier. It carried a crew of four but only one was awake and on duty. As a result of the explosion the ears of the crewman on watch at the wheel were affected for about 15 minutes; another crewman had one ear temporarily affected; and two crewmen suffered no ear pressure. The explosion knocked out the engines, took the overhead off the wheelhouse, sprayed oil over the boat, smashed out all glass and caused other damage to the boat. After an extensive survey of the damage the boat was considered to be a "constructive total loss." The crewman on watch at the wheel was cut

on the face and back by flying glass but the other crewmen received cuts only on the feet as a result of walking on broken glass.

It is interesting to note that the M.S. Redline oil tanker was on the starboard beam, the Y.P. Miahelo II was on the starboard quarter [Note. Quarter: The general direction on either side of a ship located 45 degrees off the stern], and the Governor MBM was on the starboard bow of the exploded ship, the E. A. Bryan.

In contrast to witnesses on land, who were unable to differentiate portions of the two ships and the pier within the exploding area, the witnesses on the above-mentioned boats testified to such happenings as:

(1) Saw head end of a ship foremost mast forward go up in the air.

(2) Saw pieces of dock in air with pilings attached.

(3) Saw funnel-shaped area 200 feet in air, on top of which was bow of ship with mast attached.

(4) In first flash saw shoreline and inside ship [*E. A. Bryan*]; in second explosion the inside ship and pier seemed to go together.

(5) Could see outline of dock and ship, looked like center of fireworks mostly on the ship that hadn't gone up yet. [E.A. Bryan].

Roe Island Lighthouse.

On Roe Island directly across the channel and 3,280 feet from the pier, a lighthouse was occupied by the keeper, his wife, two children, and an assistant keeper. The keeper and his wife were in the kitchen in the rear of the house at the time of the explosion. The first explosion knocked out the navigation light, broke all windows in the house, blew furniture about and shook the house violently. Although the two children were

showered with glass neither one had a single scratch. The assistant keeper and the parents of the children likewise were not injured.

The keeper of the light testified as to his recollections while in the kitchen during the first explosion and during the second explosion while looking out the upstairs window, especially as to the 20 to 30 foot water wave coming toward the lighthouse from the direction of the pier. Although this unusual water wave for Suisun Bay put the lighthouse boat 40 feet back on the beach and tore down bulkheads, there was no evidence of oil sprayed on Roe Island. On the other hand, the Y. P. Miahelo II patrol boat was sprayed heavily with fuel oil, apparently by either the same or similar water wave that was observed by the lighthouse keeper.

A large number of missiles were found on Roe Island including several lengths of railroad car rails and many pieces which were recognized as parts of railroad cars. The significance of these particular missiles in relation to the possible origin of the explosion will be considered later in the section on missiles. Some parts of the bodies of the loading details and ships' crews were recovered on Roe Island. Some parts were washed on the island probably by the so-called "tidal wave" and other parts probably were blown directly onto the island by the force of the explosion.

Southern Cities and Towns.

Port Chicago.

The town of Port Chicago, lying adjacent to the barracks and administration area of the Naval Magazine and 1 to 2 miles from the loading pier, not only received extensive damage from the blast wave but also was hit by scattered missiles from the exploding ship. Although the main street of Port Chicago was roughly parallel to the direction of the blast wave, many occupants of commercial buildings suffered extensive damage to merchandise by the breakage of large plate glass windows and cases. Window glass breakage, plaster dam-

age and other superficial damage, and personal property damage to household furniture was extensive in the residential parts of the town.

Many automobiles in Port Chicago were damaged by the blast wave and some by missiles. Steel tops were mashed in, windows broken, doors sprung, fronts and fenders dented. For example, an automobile parked beside the Southern Pacific Depot had a 3 inch diameter hole torn in its steel body by the penetration of a metal slug; the ribs in top were broken; doors were sprung and all glass was broken. Another car, parked in front of the depot, had its top and sides blown in, all glass broken and upholstery out. A woman occupant of this car was not injured. A car, parked across the street from the theater, was struck by a missile, and two doors, a running board, and a door post were crushed.

A two-ring circus was in town the night of the explosion and the damage to their trailer equipment was surveyed by experienced men from a nearby government installation. It was verified that nineteen tires were destroyed on twelve of the eighteen trailers. The claims for damages to automobiles parked on the streets of Port Chicago did not indicate that any tires were destroyed either by missiles or by the blast wave.

In the town of Port Chicago only one building, an unoccupied shop which lacked proper maintenance, completely collapsed. A large storehouse in fair condition partially collapsed and the remainder had to be torn down. The sidewall of a theater partially collapsed but the patrons vacated the building before the roof fell. Several poorly constructed frame buildings, used for commercial purposes, had partially collapsed side walls and roofs. As a whole, the structural damage to all types of buildings was mainly to the roof and associated members and was minor as compared with the dollar amount of superficial and glass damage.

The injuries associated with structural damage were few. The magnitude of personal property damage by broken glass, flying glass, and broken doors indicates, however, the possibility of a greater number and more serious injuries if the explosion had occurred when people were active and walking in rooms rather than late at night when most people had retired. The greater protection of a horizontal position and lack of panicky actions no doubt resulted in the low injury rate. There

is evidence that many of the windows and doors had blown in before the occupants were aroused sufficiently to move about and be subjected to the hazards of the second explosion.

Glass Breakage.

Window Glass.

Every claim for glass breakage was recorded separately, by cities and towns, as to the sizes and number of panes of glass broken, the type, such as single strength (ss), double strength (ds), plate, and wire, and the dollar amount for replacement. Later a tabulation was prepared showing, by cities and towns, the number of claims. These data were transferred to a percentage relationship of the total houses damaged in a city or town. The glass damage criterion for cities and towns indicates a straight line relationship with the southern cities showing a more consistent trend than those of either the western or eastern cities. This exhibit indicates the rapid decrease in damage with greater distance from the pier. Of particular interest is the apparent limit of breakage of similar types of glass between 22 and 24 miles. This apparent limit of breakage of small sizes will be considered in the section on plate glass, especially as to its significance in relation to mathematical calculations by the National Defense Research Committee of probable window glass breakage of a particular size at twenty-five miles from the Port Chicago explosion.

Plate Glass.

Plate glass breakage was extensive with much damage to merchandise displayed in store windows. The amount of breakage, in general, follows a straight line relationship with greater distance from the pier.

The National Defense Research Committee, in a chapter on the rupture of glass ("Study of the physical vulnerability of military targets to various types of aerial bombardment." NDRC Report No. A-385, pp. 297-298. Confidential) chose Port Chicago as an example for the use of certain equations derived therein for the determination of the radius of

glass breakage by sizes. On the basis of the weight of explosives detonated of 4,272,000 pounds and glass breakage up to 25 miles given in an earlier abstract of the explosion and on the assumption of "face-on" conditions, it was stated, "12 x 18 x 0.12 inches glass should not be broken, but larger panes such as 24 x 24 x 0.12 inches would be expected to be broken under favorable conditions."

A review of the basic sheets on glass breakage shows that the greatest distance of breakage of window panes comparable in size to 12 x 18 x 0.12 inches was at Oakland, California, a distance of about 22 miles from the pier. The theoretical calculation by N.D.R.C., therefore, is substantiated by complete data on actual window breakage as a result of the Port Chicago explosion.

[Note. Reference in the two paragraphs above is made to NDRC Report No. A-385, a report that employed comprehensive data on window glass breakage caused by the Port Chicago explosion to formulate equations to predict the radius of glass breakage, by sizes, which would result from various types of aerial bombardment. The TNT charge weight cited from Report A-385 for the Port Chicago explosion, 4,272,000 pounds or 2,136 tons, is said to have been "given in an earlier abstract of the explosion." Report A-385 presumably provides a specific citation for that "earlier abstract of the explosion," but Report No. A-385 cannot be located; consequently neither the title of that "earlier abstract of the explosion" nor the Government agency that produced it is known.]

VIII Appendix. C. Suisun Bay Crater.

In Mud Bottom. (Quoted from, Records of Proceedings of a Court of Inquiry, The U.S. Naval Magazine, Port Chicago, California, July 21, 1944.)

"Soundings of the bottom of Suisun Bay in the vicinity of the U.S. Naval Magazine Ship Pier were made between February 26 and March 11, 1944, and again between July 25 and July 29, 1944. A comparison of the maps prepared in these two survey yielded information about the crater formed in the Port Chicago explosion of July 17, 1944. The

contour maps and profile diagrams indicate that a crater about eight feet in maximum depth was scoured out by the explosion of the S.S. E.A. Bryan. As might be expected, the crater by no means exhibits circular symmetry in a horizontal plane, but is roughly in the shape of an oval or ellipsoid, whose major axis is parallel to the direction of the exploding vessel. The bottom of the crater is located directly under the center of the ship. At a depth of 33 feet (approximately the mean depth near the pier prior to the explosion) the crater diameter along the major axis of the ellipsoid was roughly 600 feet, and along the minor axis, nearly 300 feet."

In Hard Bottom. (Extracted from: "Soil Investigation Naval Magazine, Port Chicago – Soundings to determine extent of crater created in Suisun Bay by the recent explosion." Contract report by L. Cedric Macabee to Public Works Officer, Navy Yard, Mare Island, 28 March 1945.)

The Bureau of Yards and Docks of the Navy Department authorized a survey of the area of the exploded ship by means of probings, boring, and other devices so as to ascertain the extent of the original crater at Port Chicago. An area of about 700 square feet was investigated by probing through the loose mud overlying the crater area to the undisturbed surface of the hard bottom of the original crater.

A rectangular grid of the area was laid out with lines 100 feet apart except within the critical area where the lines were 50 feet apart. A special probing tool, one-inch round, was pushed down at 10 to 25 foot intervals along the lines to determine the depth of the hard bottom below the mud line. The survey started in November 1944 and was completed in March 1945. The lateral force of the explosion was evident to the contractor, as he reported, by the probable total removal of the soft mud from the vicinity of the blast and its partial return with the water in the form of a tidal wave. There were, therefore, two tidal waves that resulted from the explosion: The first moved outward from the explosion center onto low-lying shoreline areas and across Suisun Bay to Roe Island; the second, carrying a large volume of soft mud,

rushed back into the region where the explosion had occurred to restore the volume of water that had been expelled outward by the explosion in the first tidal wave.

Miscellaneous findings of the report included the following:

(1) Steel obstructions were encountered at 81 feet (elevation minus 81) below mean low low water (MLLW).
(2) Many local small deep holes appeared in the hard bottom in the crater area.
(3) Mud balls up to four feet in diameter were found on the mud bottom by salvage divers.
(4) Pilings of the shiploading pier were broken off at the mud line.
(5) Heavy parts of a ship, later identified as parts of the Quinault Victory, were found northward in the Suisun Bay shipping channel, approximately 2,000 feet from the origin of the explosion.
(6) Two distinct craters were identified on the south side of the shiploading pier and a lesser crater on the north side of pier.

The extent of the original crater was expressed by the contractor's report as follows:

"It is our opinion the craters as shown on contour map of depth of probing, cross-sections of the area, the evidence of individual smaller holes and metal considerably below the general outline of the craters blasted out in the 'hard bottom' of the bay give the location of the crater of the blast and the tremendous downward force . . . The extent of the mud crater caused by the explosion was possibly 800 feet in diameter measured from the center of the blast."

Photographs and illustrations credits.

Diagram, Port Chicago Naval Magazine, ships and piers. Source: "The Port Chicago, California, Ship Explosion of 17 July 1944." Army-Navy Explosives Safety Board Technical Paper No. 6. Washington, D.C., 1948; page 13.

Twenty-five of the 30 men of the Navy Armed Guard crew of the E. A. Bryan killed in the explosion. Source: Courtesy of Thomas R. Bowerman, http://www.armed-guard.com/02peo.html.

Map of maximum boundary of missiles. Source: "The Port Chicago, California, Ship Explosion of 17 July 1944." Army-Navy Explosives Safety Board Technical Paper No. 6. Washington, D.C., 1948. VIII. Appendix B. Missile Analysis; page 7.

Sketch of position of boats in channel to destroyed pier. Source: "The Port Chicago, California, Ship Explosion of 17 July 1944." Army-Navy Explosives Safety Board Technical Paper No. 6. Washington, D.C., 1948; page 25.