The Trinity Experiments

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Prepared for White Sands Missile Range, New Mexico

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Cover photograph: George A. Economou and Benjamin C. Benjamin (with hat) setting up Torpex charge tripod (WSMR photograph file).

PREFACE

On July 16, 1945, at 5:29:45 a.m. Mountain War Time, the world entered the Nuclear Age with the successful detonation of the first atomic bomb. Over the years, numerous books and articles have been written about the Manhattan Project and the Trinity site. Many of these discuss the national and international social and political conditions and issues relating to the development of the atomic bomb. Other publications take the historical approach, providing a chronology of events that led to the detonation of the bomb and its aftermath.

The Trinity Experiments is the first study of the actual experiments associated with evaluating the effects of the explosion. The study is very timely because, during the last year of this study, several scientists associated with the Manhattan Project and nuclear physics have passed away. They include K.T. Bainbridge, Director of the Trinity Project; Alexander Langsdorf, Jr., a pioneer in plutonium physics; C. E. Wiegand, a physicist; and J. Carson Mark, a physicist with the hydrogen bomb. Henry Barshall was interviewed about his participation with the excess velocity gauges; he passed away a couple of months after being interviewed.

Using oral interviews of scientists and their post-blast technical reports, plus historic photographs, Mr. Merlan has documented how the scientists adapted and modified their experiments from the original plans developed at Los Alamos and how they made do with the technology at hand, with no idea of the final magnitude of the explosion.

The Trinity Experiments is written for the general audience. Through the clearly written and nontechnical descriptions and illustrations of the experiments, the reader gains an understanding of how the first atomic explosion was recorded.

David T. Kirkpatrick, Ph.D.
Principal Investigator

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ACKNOWLEDGMENTS

Individuals interviewed for this report include Jack W. Aeby, Henry H. Barschall, Benjamin C. Benjamin, Berlyn Brixner, William E. and Margaret Caldes, Marvin R. Davis, Sr., Felix DePaula, Benjamin C. Diven, George A. Economou, J. Carlton Hoogterp, Theodore Jorgensen, Jr., Ernest D. Klema, Robert D. Krohn, Charles T. Menz, Joseph L. McKibben, Hugh T. Richards, Robert L. Walker, Richard J. Watts, Robert R. Wilson, and Edwin N. York. The author wishes to acknowledge their kindness, cooperation, and patience. Roger A. Meade and Linda Sandoval of the Los Alamos National Laboratory Archives, and Teresa A. Strottman of the Los Alamos Historical Museum kindly helped the author to locate relevant documents, maps, and photographs. Roger A. Meade read the draft report and made several corrections. Fred Rick, Public Affairs, Los Alamos National Laboratory, gave the author access to file copies of the Trinity series photographs referenced in this report. Bob Brewer, Imaging Services, Los Alamos National Laboratory, produced the positives of photographs from the Trinity series that illustrate this report. Marcy Gallegos, Reports Section, Research Library, Los Alamos National Laboratory, reviewed and released reports (as indicated in the bibliography) that had not been publicly released prior to this investigation. Robert J. Burton, White Sands Missile Range Archaeologist, read and commented on the draft report and helped the author to relocate artifacts on the site. Stephen P. Merlan photographed artifacts and locations for this report. David T. Kirkpatrick of Human Systems Research, Inc., supervised this investigation and helped the author in field reconnaissance. The author takes sole responsibility for any errors and omissions in the report.

INTRODUCTION

The first atomic test took place at Trinity Site (now Trinity National Historic Landmark) on July 16, 1945. The test was accompanied by experiments designed to measure physical aspects of the explosion, with particular attention to its destructive force. This report describes some elements of the experimental program that accompanied the atomic test, with emphasis on experiments deployed in the core area of the test (radius 1,500 yards from Ground Zero, the location of the bomb). This report should facilitate the identification of artifacts that may have remained in place after the test.

La primera prueba atómica tuvo lugar al sitio designado Trinidad (actualmente Marca Nacional Histórica) en la Jornada del Muerto de la región surcentral de Nuevo Mexico el 16 julio 1945. La prueba se acompañó de varios experimentos los cuales se dibujaron con intento de medir aspectos físicos de la explosión, con singular atención a su fuerza destructiva. Este informe acentua los experimentos desplegados en la area central de la prueba (dentro 1,500 yardas de Zero, situación de la bomba atómica) con motivo de facilitar la identificación de elementos que hayan permanecido en el sitio después de la prueba.

The first atomic explosion, at Trinity Site (now Trinity National Historic Landmark) in the Jornada del Muerto of south-central New Mexico on July 16, 1945, was measured by numerous instruments created or adapted for the occasion. The data on physical aspects of the explosion (heat, light, neutrons, gamma rays, earth displacement, blast, shock, and other phenomena) were intended to indicate what to expect of atomic bombs in combat, and how to achieve the greatest destruction (Hoddesen et al. 1993:350).

EVENTS LEADING TO THE TEST AND THE EXPERIMENTAL PROGRAM

The development of a nuclear weapon was originally suggested by Albert Einstein in a letter to President Franklin Roosevelt. Emigré scientists Leo Szilard, Edward Teller, and Eugene P. Wigner prevailed on Einstein to sign the letter, drafted by Szilard. It was delivered by presidential advisor Alexander Sachs on October 11, 1939. After some discussion, Roosevelt agreed to pursue development of a nuclear weapon.

In June 1942, J. Robert Oppenheimer of the University of California was appointed director of what became known as Project Y, or the Los Alamos Project (development of an atomic weapon). The Project Y site, the Los Alamos Ranch School, was selected in November 1942. The project was under the direction of Major General Leslie R. Groves.

Development of an implosion weapon was well along at Los Alamos by early 1944. It became evident, however, that the weapon would have to be tested. Producing a nuclear explosion was an entirely new undertaking. Trying it for the first time over enemy territory or in a demonstration might produce only a failure that could be disastrous militarily. Furthermore, quantitative information on the effects of the new weapon was necessary for planning purposes.

There was wide disagreement among the involved scientists about the explosive force to be expected. They also needed to know how the implosion system inside the device would work; what the effects of heat, blast, and earth shock might be; how much radiation would be produced; and what the attendant phenomena, such as the fireball and cloud, would look like.

The generally accepted predictions of the yield of the blast were between 5 and 10 kilotons (Hoddesen et al. 1993:376). Bainbridge (1976:1) notes that a planning session on July 10, 1945, took into account yields of anywhere from 100 to 10,000 tons, with a probable value of 4,000 tons. After the test, radiochemical analysis of the amount of plutoninm fission enabled the scientists to calculate the efficiency and yield of the blast. From the samples collected by the shielded tanks near Ground Zero after the test (see below), they calculated that the bomb had been more efficient than predicted, with a yield of 18,600 tons of TNT (the value currently accepted is 20 to 22 kilotons). "The yield [of the atomic test] was almost three times larger than predicted" (Hoddesen et al. 1993:374).

Physicist Kenneth T. Bainbridge, who was put in charge of all on-site operations, states that the measurements and observations fell under four headings: behavior of the implosion; nuclear energy released; damage effects produced; and overall behavior of the explosion and its aftereffects (Bainbridge 1976:9). Hawkins (1983:243) states that there were six chief groups of experiments—damage, blast and shock, general phenomena, radiation measurements, and meteorology. Preparations for a test began in March 1944.

The search for a location began in May 1944 (Szasz 1984:27). K. T. Bainbridge and Major W. A. Stevens eventually selected the Jornada del Muerto in September 1944 (Szasz 1984:28). On September 17, Bainbridge and several others visited the probable test site and staked Ground Zero and three observation sites—North 10,000, West 10,000, and South 10,000. Construction began in November 1944, but most of the work was done between March and July 1945. A Military Police detachment took up residence on the site in December 1944. Construction included structures, roads, haul roads, towers, communications lines, and earth and concrete bunkers.

Only a limited nnmber of measurements could be provided for during the test. Hoddesen (Hoddesen et al. 1993:351) states that a panel consisting of Lewis Fussell, Philip B. Moon, Bernard Waldman, and Victor Weisskopf evaluated all proposals. Bainbridge (1976:26), however, states that the reviewers were John H. Manley, William J. Penney, Robert R. Wilson, Enrico Fermi, Weisskopf, Julian Mack, and Waldman, with Bainbridge himself as the administrative head of the project, assuming veto power over all experiments (Bainbridge 1976:15). At a conference in Robert Oppenheimer's office on December 23, 1944, it was agreed that experiments to determine the efficiency of the reaction, the pressure of the blast wave, and the time spread in the firing of the bomb's

detonators were essential. Photographic and spectrographic analysis of the fireball was deemed to be desirable. Experiments to measure earth motion during the explosion were also deemed desirable. These were for evidentiary purposes in case of lawsuits against the government in the event of damage (General Groves requested the earth- motion records). All other experiments were deemed unnecessary (Hoddesen et al. 1993:352).

Six areas of proposed experimentation may be identified in somewhat more detail, as follows:

The physical behavior of the implosion would be determined by recording the simultaneity of the bomb's detonators as they exploded, with electronic signals sent to fast oscilloscopes at South 10,000. The interval between the firing of the detonators and the first gamma rays emitted from the explosion would be measured, and the rate at which fissions occurred would be measured with electron-multiplier chambers and a direct-deflection, high-speed oscillograph.

The energy released from the atomic reaction would be gauged by recording delayed gamma rays in ground and airborne (by means of weather balloons) ionization chambers, with information transmitted to Heiland recorders at the three 10,000-yd bunkers. Tank-mounted ionization chambers would enter Ground Zero after the blast. Cellophane catcher cameras would measure delayed neutrons at ground and airborne stations. Eight sulphur threshold detectors and a number of gold-foil detectors would also measure delayed neutrons. The conversion of ^{239}Pu fission products would be measured from post-test ground and air samples that would be analyzed radiochemically for alpha, beta, gamma, and gross-particle counts. Ground samples would be taken from the crater, while air samples would be taken above the test site by a B-29 equipped for this purpose.

The air blast from the bomb would be determined by gauging blast pressure near Ground Zero with quartz piezoelectric gauges and condenser gauges, by measuring blast velocity with moving coil loudspeaker pickups, and with blast-operated torpex charges whose explosions would be photographed. Peak pressure would be measured with spring-loaded piston gauges, crusher gauges, and aluminum-diaphragm box gauges. Remote pressure would be measured with Friez ML-3-A barographs located in surrounding towns. Blast impulse would be measured with mechanically recording piston liquid and orifice gauges. Mass velocity and shock wave would be measured by photographing the ignition of suspended primacord and magnesium flash powder.

The earth shock created by the bomb would be measured with strong motion geophones close to Ground Zero and Leet three-component string motion displacement seismographs at greater distance. Permanent horizontal and vertical earth displacement would be measured with steel stakes placed around Ground Zero. Remote seismographs would record distant tremors at Tucson, El Paso, and Denver.

The bomb's incendiary effects would be tested by evaluating the burning and charring of various materials.

The explosion would be recorded by photographing the fireball with Fastax cameras, standard 16-mm color cameras, and a 16-mm Cline-Special 24-foot-per-second (fps) camera. The fireball would be tracked by radar; the rise of the smoke column would be photographed with four 100-fps and one 24-fps Mitchell 35-mm motion picture camera, two pinhole cameras, and two gamma ray recorders. The lateral movement of the cloud would be photographed with Fairchild 9-by-9-in. Aero View cameras. Radiation would be measured with various spectrographs and photocells recording on drum oscillographs for photometric measurements.

An undated, unsigned memorandum (Record Group A-84-019, Box and Folder 53-12, LANL Archives) written about this time notes that "there is a significant difference in the blast resisting characteristics of German towns and those of Japanese towns. While in Germany a broad distinction may be made between industrial buildings and the remainder...there is no pronounced contrast in the strength of one building and another....In Tokyo and Yokohama, some areas consist entirely of extremely strong steel framed and concrete structures... whereas other...areas contain only...flimsy wooden houses..." This was part of a discussion of the altitude at which the bomb should be detonated ("height of burst") so as to maximize its destructive force. This memorandum assumes that the bomb may be used against Germany.

Simpler experiments that did not require much shop time took precedence over other experiments (Hoddesen et al. 1993:353); cost was less of a consideration.

The most important experiments were those that measured the destructive power of the bomb (Hoddesen et al. 1993:358). These included the piezoelectric gauges, the excess-velocity microphones, spring-loaded piston gauges, aluminum box gauges, condenser gauges, crusher gauges, and water-filled pistons. Mechanical gauges had the obvious advantage of being impervious to electrical disturbances.

A rehearsal shot of 100 tons of high explosive took place on May 7, 1945. A small amount of radioactive material was added to the explosive, so that its dispersion could be measured (Hoddesen et al. 1993:360). This shot tested the organization for the final shot and gave data for calibrating blast measurements (Hawkins 1983:170). Most of the instrumentation of Trinity was first used in the test shot.

METHODS AND SOURCES

The primary purposes of this report are (1) to note and explain instrumentation which may have left or is known to have left physical evidence on the site; (2) to make it possible for field investigators to relocate the instrumentation, or whatever may remain of the instrument stands; and (3) to obtain information and artifacts that may be used by the White Sands Missile Range Museum in exhibits or reconstructions relating to the instrumentation and the test itself. This report emphasizes the location, construction, and appearance of the instrumentation within a radius of 1,500 yd of Ground Zero, with particular attention to artifacts that remained in place after the test. This report is based on several secondary and primary sources.

A general discussion of the instrumentation of Trinity is contained in K. T. Bainbridge's report, *Trinity* (Bainbridge 1976), most of which was written shortly after the test. This report, however, contains errors; it is often mistaken about the number of gauges used in a given experiment. Bainbridge wrote this report hastily and appears to have used preliminary reports and plans, without checking systematically to determine whether the experiments were actually built or arrayed as planned. In various cases, experiments were reconfigured at the last minute, and in most of these cases, it was a matter of reducing the number of gauges and changing the planned locations. Where this is known to have happened or probably happened, will be noted below.

A plan labeled "Detail Location Plan—Trinity Project" and dated May 29, 1945, is on file in the archives of Los Alamos National Laboratory. This plan appears in Rieder and Lawson (1995:40) and is used here as Figure 1. This location plan shows the core area of the test site, to about 1,500 yd from Ground Zero. This plan will be referred to throughout this report as Figure 1.

A plan labeled "Trinity Project—Detail Location Plan" and dated June 23, 1945, is on file in the archives of the Los Alamos National Laboratory. This plan also appears in Rieder and Lawson (1995:38). The plan with some additions and corrections has been used here as Figure 2. This location plan shows the test site out to 10,000 yd from Ground Zero. This plan will be referred to throughout this report as Figure 2.

Small-scale versions of these two detail location plans appear in Hawkins' (1983:504-507) *Project Y: The Los Alamos Story*.

As adapted in this report, the plans indicate alignments to the instrument shelters staked by Bainbridge and Stevens. These alignments are referred to as North, South, and West, and the locations along them described below are also designated North, South, and West. As the north symbol on the plans indicates, however, none of these alignments actually runs in a cardinal direction. Figure 1 also indicates alignments East (180° from West) and Southeast (so called to distinguish it from South. Southeast is in fact 180° from North). Instrumentation not on any of these five alignments is described in the text in yards from Ground Zero by direction (e.g., "east-northeast" or "south-southwest").

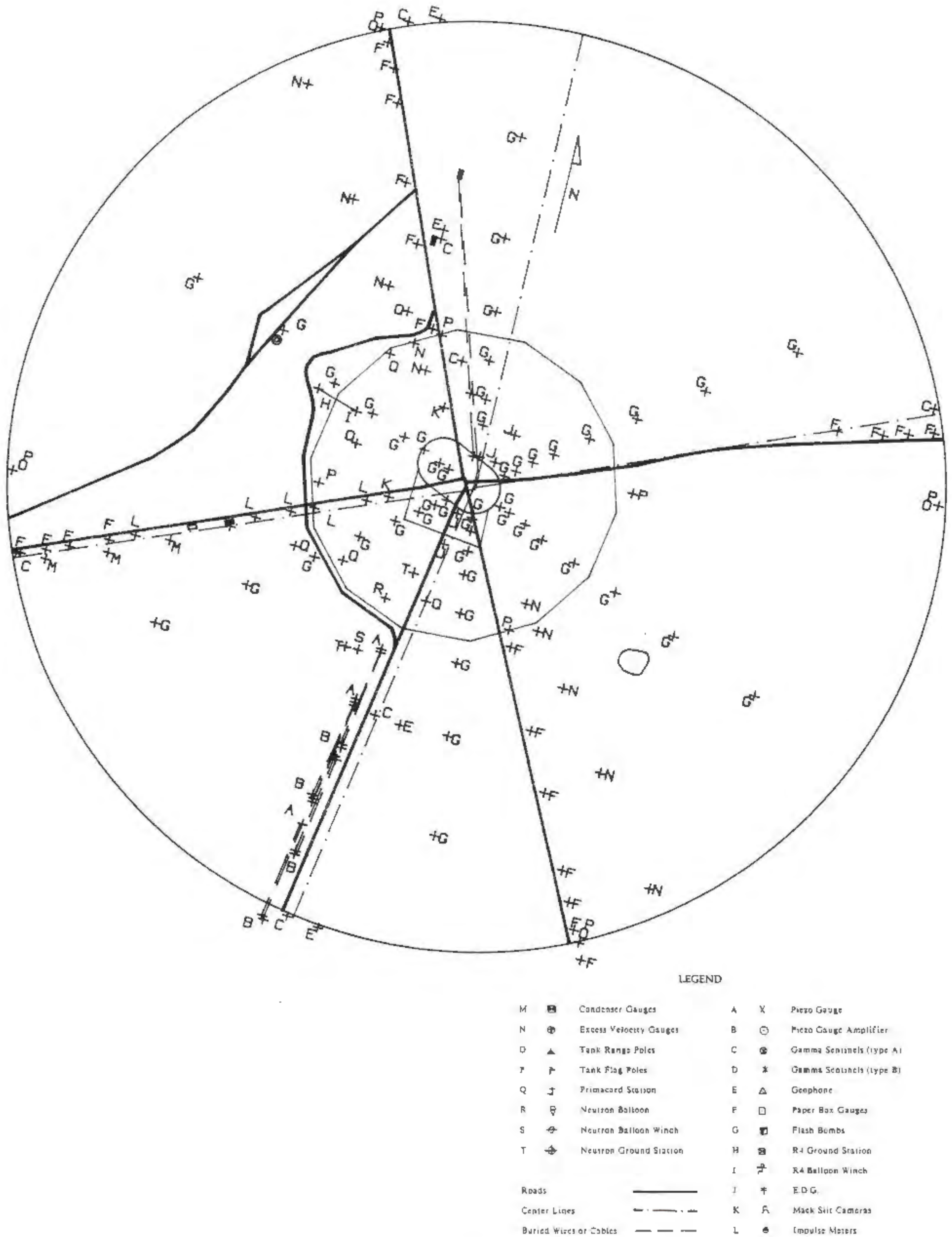

Figure 1. June 23, 1945, detail location plan of the Trinity Project.

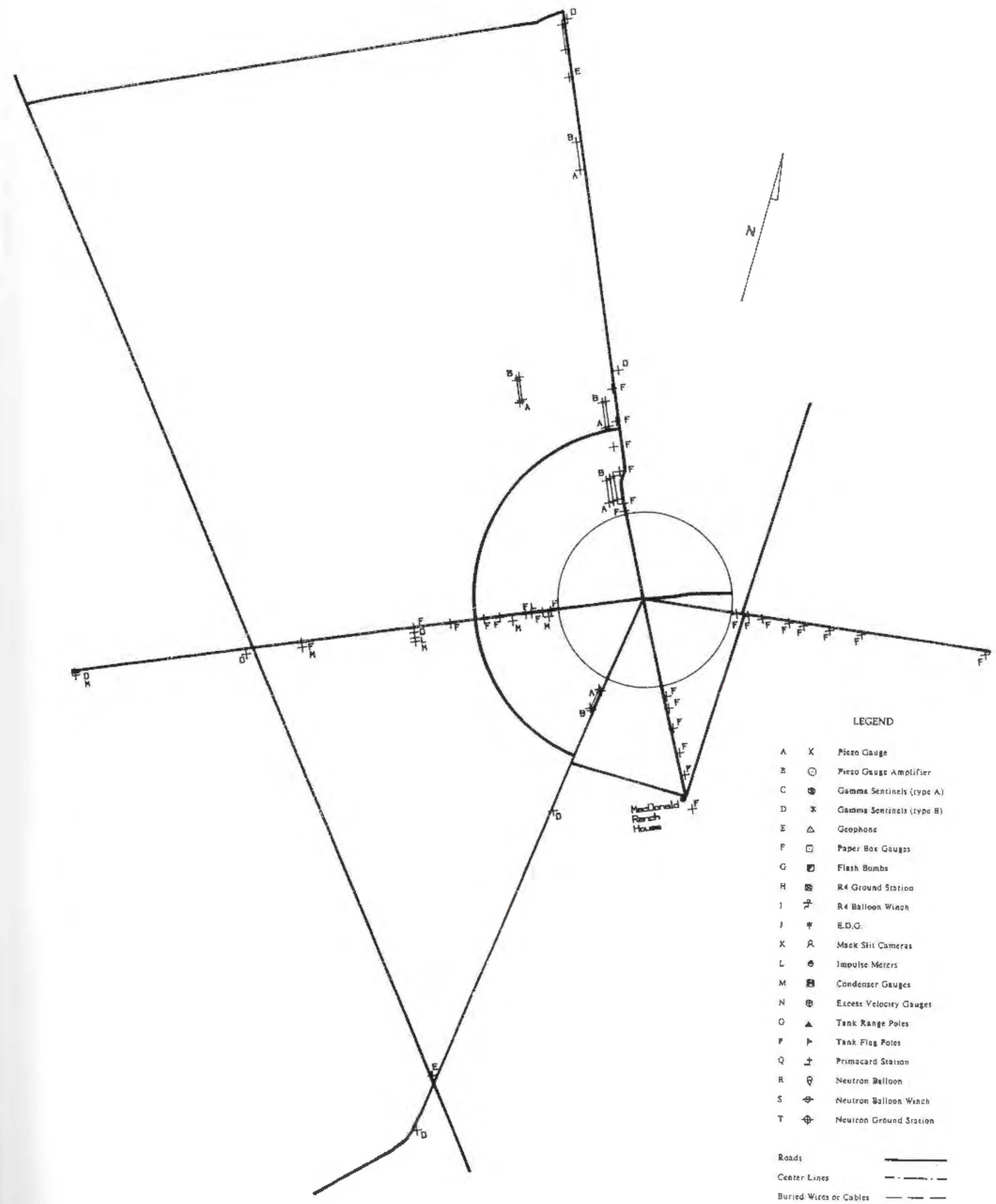

Figure 2. May 29, 1945, detail location plan of the Trinity Project.

The two detail location plans are the principal references in this report, since they illustrate the physical layout of the experimental program that accompanied the nuclear test. However, they also reveal errors of omission. For example, they do not refer to the sulphur-threshold detectors, the crusher gauges, or the peak pressure gauges in the core area of the test. Some of the experiment locations given on these plans are also wrong. When the detail location plan does not include an experiment, it is not shown on Figure 1, but this report will describe and locate the experiment on the basis of cited reports. When Figure 1 is wrong about a location, this report will offer further information.

Most of the Trinity scientists wrote or contributed to reports relating to the instrumentation. Some of these reports relate to the 100-ton (May 7) test and are then followed by reports on the behavior of the instrumentation during the atomic test. They are referenced in this report. These reports are the most detailed and accurate sources on individual experiments. They correct the two detail location plans and are probably also more reliable than personal recollections of events of more than 50 years ago.

Several of the Trinity scientists have written articles and memoirs, both published and unpublished, about the test and the instrumentation.

The Public Information Office of Los Alamos National Laboratory has on file a series of photographs labeled "Trinity Series," with alphanumeric designations TR-1 through 800. Several of these photos appear as illustrations in this report; various others are referred to.

The Los Alamos National Laboratory Archives holds Record Group A-84-019. These are surviving records of the Y Project, sorted by box and folder, and are referred to throughout this report.

The system proposed for the use of color-coded identification badges by personnel involved in the Trinity experiments and test is given in Appendix 1.

This report also references interviews with 21 surviving Trinity scientists, technicians, and military personnel (see Appendix 2). Thirteen of these were interviewed in person. The interviews were recorded in the period from May 1996 through July 1997. A further eight scientists were interviewed by letter and telephone call. Those interviewed were asked to comment on the Bainbridge report and the two plans, supplementing and correcting them with their own recollections. Some discrepancies emerged. As mentioned, the Bainbridge report is sometimes mistaken about the number of instruments in an experiment. The Bainbridge report does not fully agree with the detail location plans, and in some cases the scientists interviewed depart from both. As noted above, the individual reports written in late 1945 are usually the most reliable source. Discrepancies among the sources will be noted below, and resolutions offered where possible.

TRINITY EXPERIMENTS—THE PHYSICAL REMAINS

Shelters

Construction crews built bunkers at West 800, North 800 (Figures 3 and 4), and North 1,000, a bunker at Northwest 600, personnel shelters at North, South, and West 10,000, and camera shelters and generator bunkers adjacent to each of these last three (Figure 5).

Figure 3. The bunker at North 800 before the test (TR-43).

Figure 4. The bunker at North 800 after the test (TR-424).

Figure 5. The personnel shelter at North 10,000 (TR-45). Camera shelter in center of picture.

The following construction drawings are in the archives of Los Alamos National Laboratory:

Concrete Recording Chamber, Drawing No. Y-1459D-1A, 9-30-44
Bldg. No. 1, 11-1-44
Bldg. No. 2, 11-1-44
Preliminary Sketch of Personnel and Instrument Shelter (n.d.)
Concrete Recording Chamber, 9-30-44
Bldg. No. 3, 11-1-44

"Bldg. No. 1" corresponds to the bunkers at West and North 800. The "Concrete Recording Chamber" is the same structure. The two bunkers were nearly identical as built. Each measured 6 by 6 ft by 6 ft 7 in. high (interior), and had three small viewing ports on the front wall, shielded by protective concrete pipes approximately 16 in. in diameter by 8 ft long, open at the far end to give a view of the tower at Ground Zero. There was a fourth viewing port on the right side wall. All four ports were covered with bullet-proof glass.

The bunkers were half buried and covered with 2 ft of earthen fill topped by an angled concrete slab 12 in. thick. The bunkers were made of reinforced concrete with 6 in. thick floors and walls, and a 12 in. thick ceiling. Each had a rear door measuring 30 in. wide and 36 in. deep.

The entrance to the bunker at West 800 had low timber retaining walls shielding it. Both bunkers had timber wing walls to the left of the door and on the right front side. The wing walls were anchored to buried log deadmen with steel tie rods.

Wiring and equipment were attached to the interior wooden forms that were used to construct the bunkers and then left in place.

Both bunkers contained high-speed Fastax cameras to record the first milliseconds of the test—that is, the early stages of the explosion. Each had a focal length of about 35 to 50 mm. They were placed close to Ground Zero to minimize atmospheric disturbance. However, after the 100-ton test and before the nuclear test it was decided to put the Fastax cameras on lead-lined steel sleds (pictured in TR-255 and 402) attached to steel cables about 1,000 ft long. This was done to make it possible to haul the cameras out of the test area.

"Bldg. No. 2" is a personnel shelter, probably corresponding to North, South, and West 10,000. "Bldg. No. 3" does not clearly correspond to anything as actually built (although it is possible that it generally corresponds to Northwest 600), while "Bldg. No. 4" is a camera shelter, possibly at North and West 10,000.

The North 1,000 and Northwest 600 bunkers were about the same size as the 800 bunkers. They were made of reinforced concrete and were covered with earthen fill, although they had no concrete top slabs or viewing ports. The Northwest 600 bunker had two 5-in.-diameter metal pipes projecting about 18 in. above a rectangular concrete base that projected from the roof of the bunker. These were the supports for an ionization chamber detector that was destroyed by the atomic blast (Jack Aeby, personal communication 1997). The North 1,000 bunker had a small metal pipe, about 1 1/2 in. in diameter by 18 in. long, projecting from the roof. Each bunker had a door facing away from Ground Zero. The door to Northwest 600 was below grade, with earth-and-wood stairs protected by timber retaining walls.

A wood addition of heavy timbers about 10 ft square was attached to the rear of North 1,000 to hold an air conditioner to keep instruments cool.

One of the cellophane catcher cameras (see below) may have been sheltered in Northwest 600. According to one source, North 1,000 contained radiation-measuring equipment (Historic American Building Survey [HAER] n.d.). A memorandum dated May 18, 1945, from Robert R. Wilson to John H. Williams (Record Group A-84-019, Box and Folder 54-15, LANL Archives) states more specifically that it contained electronic equipment for measuring alpha and implosion time. William E. Caldes, a civilian engineer who worked in Robert Wilson's group, spent most of his time at Trinity in this bunker. Caldes described the bunker:

> Our basic assignment had to do with getting measurements of fast and slow Gamma rays from the blast. My job was the fabrication and installation of most of the electronic gear to be used. Since there was no way of telling in advance what the magnitude of the measurements might be, five sets of measuring equipment were set up, each one set to measure a different range or magnitude, in hopes of one being right. In 1945, there were no micro-electronics, no transistors or integrated circuits, no solid state devices of any type, no tape recorders, and

certainly no video or CD recorders. Circuitry that now would take only one square inch of space required a metal chassis three by twelve by eighteen inches. There must have been about three dozen such chassis along with oscilloscopes, cameras, and trigger circuits all mounted in large racks. These were jammed into a crowded under-ground concrete bunker, one thousand yards from the tower...[Caldes n.d.:50-51]

The personnel shelters have now been demolished, but the camera shelters still exist (Mary Slater, personal communication 1996). The bunkers at West 800, North 800, North 1,000, and Northwest 600 are also still standing, although in deteriorated condition (Slater 1996).

The personnel bunkers at North, South, and West 10,000 were also camera stations. There were two Fastax cameras in each shelter, each with a focal length of about a foot. Each shelter also housed one Fairchild K-17-B aerial camera with a 12-in. lens, adjusted to take a 9-by-9-in. picture of a wide field every 3 seconds until its 200 ft of film was exhausted. Each shelter also contained a pinhole camera with an image distance of 60 in. Mounted in the vestibule roof of two of the shelters was an electrically-operated Martin machine-gun turret modified to serve as a pan-tilt head (TR-201). These were the only camera instruments that were hand-controlled, one by Julian Mack and the other by Berlyn Brixner. Also mounted on each turret were a spectrograph, a Mitchell high-speed 35-mm motion picture camera and eight motorized 16-mm Cine Kodak Es. Most of these last were loaded with Kodachrome film. In fixed positions next to the turret were another Mitchell camera, about eight Cine Es, and a time-exposure camera with a focal length of 2 m. There were two K-17-B or Fairchild aerial cameras, one on a hill northwest of the test site and one on another hill .5 mile to the east of the first.

The literature generally refers to this location as Campana Hill. However, a contemporary photograph (TR-150) appears to show the hill now known as Red Butte, not Campana Hill. Campana Hill, although highly visible because of its commanding height and the bell shape from which its name is derived, is behind a series of hills including Red Butte and has no convenient access. Further, the White Sands Missile Range archaeologist examined it from a helicopter and saw no sign of roads or any other development (Robert J. Burton, personal communication 1997). It may be that Campana Hill (or Campaña Hill, or Compania Hill, as the Trinity literature and correspondence variously call it) is just a convenient designation for the whole range of hills.

The cameras were controlled to open simultaneously and to give stereopairs at 3-second intervals. Communications lines (Signal Corps twisted pair wire) were strung between them from a jeep (TR-149) to enable the operators of the two cameras to talk to each other and to trigger the shutters at the same time. The cameras were obtained from the Army Air Corps (Edwin N. York, personal communication 1997). The signal wire, however, did not carry the signal rapidly enough to open the shutters simultaneously, so the pictures taken were not actually stereopairs (Edwin N. York, personal communication 1997). A single Fairchild was also set up at 20 mi in the opposite direction

(Record Group A-84-019, Box and Folder 55-16, LANL Archives: "Photographing the Atomic Bomb" by J. Mack and B. Brixner).

The personnel bunkers at North, West, and South 10,000 have been demolished. Reinforced-concrete camera bunkers at North and West 10,000 are still standing, but their wood interiors, wood-frame additions, wiring, and instrumentation have all been removed. There is no remaining structure or any other construction at South 10,000.

A station at North 100 consisted of a concrete slab 8 by 8 ft, with a lead, iron, and masonite neutron and gamma shield on it about 6 by 6 ft at the base by 4 ft high. The shield contained alpha scopes and electronic equipment. A 2-kW generator in a copper box sat next to it (memorandum dated May 18, 1945, Record Group A-84-019, Box and Folder 54-15, LANL Archives).

A station at North 300 consisted of a concrete slab 6 by 6 ft. On this was a gamma shield about 4 by 4 by 3 ft, "containing similar but less equipment" (memorandum dated May 18, 1945, Record Group A-84-019, Box and Folder 54-15, LANL Archives).

A small firing station was located at West 900 (see Figure 1) to hold the firing and timing switches for the signal cables running from South 10,000 to the tower at Ground Zero and to nearby field instruments. The station was built of timbers and set at ground level. Remains of this station were located in 1968 (HAER n.d.) and may still be on the site.

None of the drawings is labeled "final" or "as-built." The internal evidence suggests that they are all preliminary. A copy of each of the above is on file in the offices of Human Systems Research, Inc., in Las Cruces, New Mexico.

Instruments

Ground Zero: Tower and Coaxial Cables

General

The 100-ft steel tower on which the bomb was exploded was vaporized by the blast, but two tower footings survived and are described in Reines (1945).

A memorandum (Record Group A-84-019, Box and Folder 54-15, LANL Archives) states that Ground Zero was the location of the bomb [gadget] itself, with two neutron detectors [ionization chambers] positioned 3 m from the bomb, telephone lines to the North and South 10,000 bunkers, and a detonation simultaneity detector.

The tower was the bottom half of a 200-ft Blaw-Knox tower (in common use by the Army Signal Corps for mounting SCR-271 radar antennae). When set up on its footings, the tower was 102 ft high, with a base about 25 ft square and a top platform about 15 ft square. The tower base was poured in May 1945. The tower was built from June 6 through 18, 1945 (memo from Bainbridge dated June 15, 1945, A-84-019, LANL Archives). A standard Army hutment (personnel shelter) and camera shelter were built near the tower.

The plutonium core of the bomb was driven down from Los Alamos in the back seat of a Plymouth sedan on July 12, 1945. Other elements had already been trucked in. Preliminary assembly, which included assembly of the bomb's detonators, and installation of special switches and circuits to check the simultaneity of the detonators, took place on July 13. The degree of simultaneity necessary for an efficient implosion of a nuclear bomb was unknown; the switches were designed to send signals to oscilloscopes at South 10,000, where cameras would photograph the traces.

The bomb was hoisted up the tower on the morning of July 14. Final assembly took the rest of the day. On July 15, final tests on the circuit controls were conducted. Late that evening, an arming party connected the detonating circuits at the tower. The next morning at 4:45 a.m., the party closed the arming switches at the base of the tower and the firing and signal switches at the firing station at West 900. Forty-five minutes later, the bomb detonated.

The tower was built of bolted steel sections and erected in 25-ft levels, each of which was cross-braced. Each of the four legs of the tower had a 7-ft-deep reinforced-concrete foundation. Because the foundation anchor bolts were placed wrong, offset plates were welded to them and covered with concrete. This raised the tops of the foundations 2 ft above grade.

Two coaxial cables (Figures 6 and 7) extended from the tower, connecting to ground points at 100 and 200 ft north. The cable at 200 ft north continued as a thin copper wire in a trench 3 ft deep to the North 10,000 bunker. It served as a signal wire between the bunker and two neutron detectors and the detonator-simultaneity detector located at the top of the tower.

Robert R. Wilson and his group were given the task of measuring the multiplication of fission neutrons during the atomic test (simply put, the speed of the nuclear reaction). The Wilson group performed two experiments. In one, they fed the signal from a set of electron multiplier tubes that measured the gamma rays given off in the explosion into an oscilloscope whose signal was inversely proportional to a (alpha, the time for the neutron population to increase by a factor e, the base of the natural logarithms). The signal was stored in a charge collection box built into the face of the oscilloscope. The second experiment used the detector from the first experiment and a similar one placed at a different distance from the bomb. An electronic timer measured the time difference between pulses from the detectors and generated a signal proportional to the time difference. From this signal the group determined a.

Bruno Rossi (1984) set up an alternative method of measuring a. Rossi used ionization chambers to record the flux of gamma rays and to feed a voltage directly to an oscilloscope.

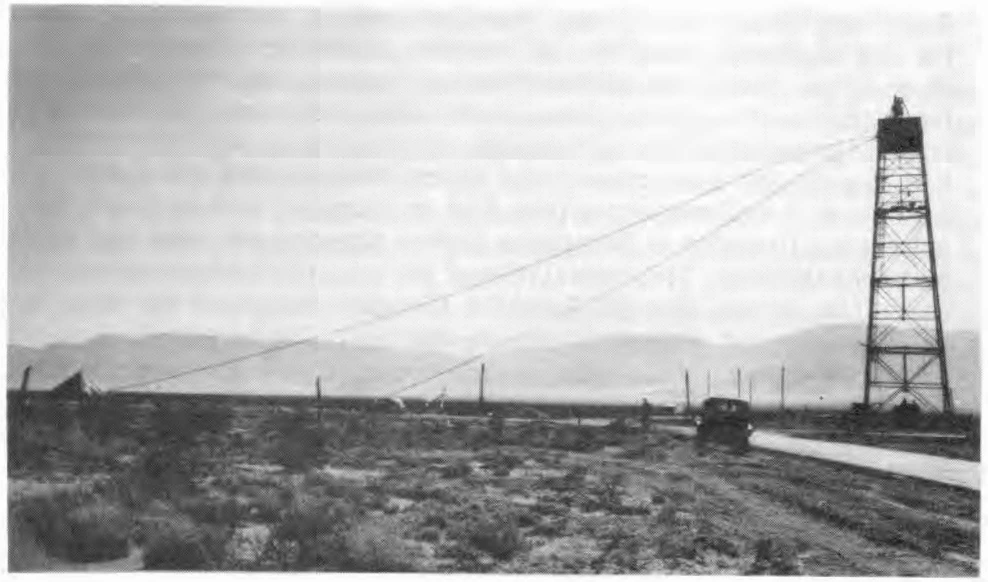

Figure 6. 100-ft tower and coaxial cables (TR-278).

Figure 7. Closeup of coaxial cables, showing the thicknesses of copper sheathing (TR-783).

> Rossi and Wilson solved one other problem. It was important for the ionization chamber and electron multiplier tubes to be close to the gadget [bomb], but the oscilloscopes had to be far from the blast to avoid destruction. They designed a line to transit the pulse without diminishing it. Drawing on advice from E.M. Purcell, the transmission line expert from the MIT Rad Lab, Rossi used a hollow copper tube 3 in. in diameter with internal cylinders of copper of decreasing radius tapering off from the end near the blast. The central part of the line was a thin copper wire. The device allowed Rossi to increase the pulse at the oscilloscope end without using an amplifier. [Hoddesen et al. 1993:356]

Location

Construction started on the 100-ft steel tower at Ground Zero on which the atomic bomb was to be placed in May 1945. The tower and everything on it was vaporized by the blast, except for the footings, which still mark Ground Zero. The cables also disappeared, but presumably the length of copper wire underground is still in place. The personnel shelter has been demolished, but the camera shelter that was adjacent to it is still standing.

Configuration

Figure 6 shows the tower and both the steel cables (straight lines extending north) that supported the coax cables, and the coax cables attached to the support cables. Benjamin Diven (personal communication 1996) notes that one coax cable is part of Wilson's two-chamber method of measuring neutron multiplication (Bainbridge 1976:63) and that the other is associated with the Rossi single-chamber method of measuring neutron multiplication. Diven (personal communication 1996) speculates that Rossi's cable is the lower of the two, as shown in TR-278, 430, and 783. Rossi says:

> I proposed an experiment which was accepted and, in fact, turned out to be the most successful of three experiments that were carried out for a similar purpose....The experiment was designed to measure the rate of increase of the [gamma] radiation emitted by the exploding gadget....Since the ionization chamber must be located near the gadget [bomb] while the recording oscilloscope must be placed at a sufficient distance so as not to be destroyed by the blast, the problem arose of connecting the chamber to the oscilloscope with a suitable transmission line....In its final design the transmission line was essentially an oversize coaxial cable. The outer electrode was a pipe, 3" in diameter. At the ionization chamber, the inner electrode had a large diameter, so as to match the chamber's low impedance. With its diameter decreasing stepwise, this electrode reached the oscilloscope as a thin wire, matching the oscilloscope's high impedance. [Rossi 1984:35-39]

Comments/Results

After the test, scientific personnel went into the test area in a lead-lined tank to take soil samples with rocket-fired ground scoops. They found the ground covered with a greenish low-grade glass (sand and dirt fused by the intense heat of the blast), later named Trinitite. They also found a crater about 1,200 ft in diameter and about 6 ft deep. The tower was vaporized; nothing of it was left except remnants of the reinforced-concrete foundations, which were driven several feet into the earth by the force of the blast. A shed was built after the test (and rebuilt in 1984) several hundred feet west of Ground Zero to cover a section of the crater and the Trinitite on the surface. The rest of the site was regraded to bury contaminated soil.

The single-chamber experiment designed by Rossi yielded a substantially accurate indication of the neutron multiplication created by the blast. Wilson's dual-chamber experiment yielded a result as well, but one substantially less accurate than Rossi's.

Sources

Bainbridge 1976:15, 29, 30, 39, 42, 43; Benjamin C. Diven, personal communication 1996; Hoddesen et al. 1993:355-356; TR-185, 278, 430, 774, 775, 783; Reines 1945.

Piezoelectric Gauges

General

Bainbridge (1976:11) notes that piezoelectric gauges were used to measure blast pressure at ground level.

Condenser gauges dropped from airplanes, a moving coil loudspeaker pickup, blast-operated switches, and torpex charges were also used to measure blast pressure.

> One device for measuring blast wave pressure had been in existence for some time at ordnance proving grounds: a pressure gauge based on a piezoelectric quartz crystal, the electrical characteristics of which changed in response to pressure. [Hoddesen et al. 1993:359]

Location

Walker notes that:

> ...gages [sic] were placed along two lines from the charge, approximately 124° apart. The north line extended in a direction about 22° west of north and had its recording equipment at Shelter A, N 10,000 yds. The south line extended in a direction approximately 34° west of south and had its recording equipment at Shelter B, S 10,000 yds. [Walker 1945:4]

Figure 1 shows gauges at South 600, 610, 780, 790, 800, 970, 980, 1,200, and 1,210. There is no indication of any gauges on the north alignment. However, Dr. Walker's recollection (Robert Walker, personal communication 1996) is that there were approximately six gauges on the north alignment and six on the south, and that all were made in Los Alamos. He does not recall any gauges made in England.

Configuration

The gauges were quartz crystals stacked in a pile and connected in parallel by copper electrodes (Figure 8).

According to Walker (1945:4), the gauges were mounted 6 ft above the ground on the horizontal arm of an inverted L-shaped pipe, the arm extending toward the shot. The gauge was insulated electrically from the grounded pipe by having the gauge stem fit through holes in rubber stoppers, which in turn fit into the pipe mount (Figure 9).

The gauges were connected to their amplifiers by means of approximately 1,000 ft of English-manufactured coaxial cable, Telconax KIC. The length of cable was determined by the length of record desired after the blast reached the gauge and before it reached the amplifier. The cable was threaded through the pipe gauge mount and then buried in garden hose about 10 in. underground, emerging at the amplifier.

As noted, Walker (1945) states that four British-made gauges were obtained from the Road Research Laboratory in England, while Dr. Robert Walker (personal communication 1996) states that all the gauges were built and tested in John Manley's laboratory at Los Alamos.

Comments/Results

The piezoelectric gauges were installed for the May 7 (100-ton) test. They yielded pressure readings about 5 percent too high (Walker 1945:13) because of the method of calibration. When used again in the Trinity test, however, they gave no records because the traces were thrown off scale by radiation effects.

Sources

Bainbridge 1976:11, 64; Hoddesen et al. 1993:359; Walker 1945; Robert L. Walker, personal communication 1996; Figure 1. Bainbridge (1976:11) states that "eleven quartz blast gauges were installed." Walker (1945) has it that seven gauges were quartz gauges, but four were of another type, obtained from the Road Research Laboratory in England.

A memorandum from Walker to Manley et al. dated March 27, 1945 (Record Group A-84-019, Box and Folder 53-13, LANL Archives), proposes 16 gauges. The total number was probably reduced before the May 7 test.

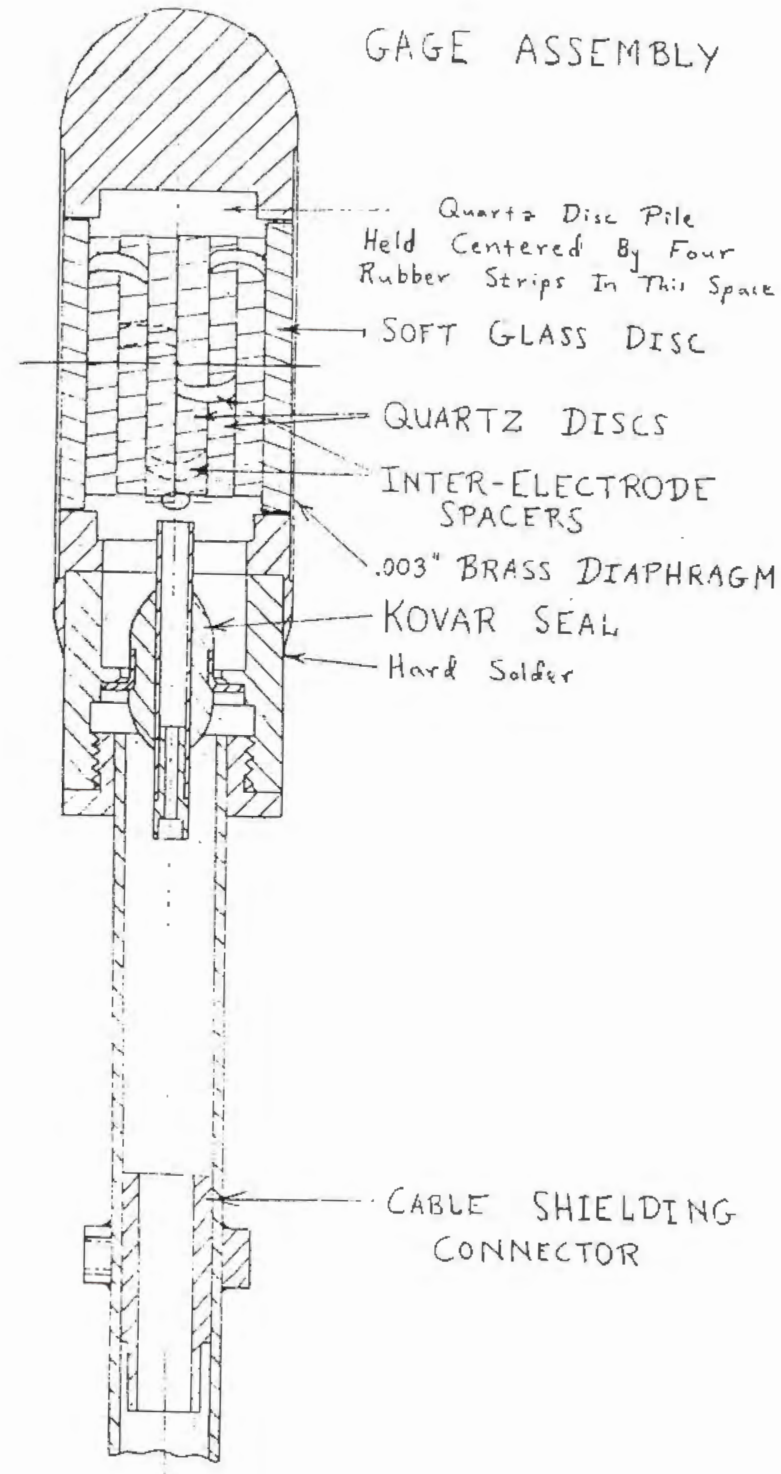

Figure 8. Piezoelectric gauge (from Walker 1945).

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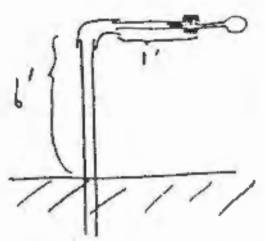
IV. Installation:

Gage to be mounted to 6 ft. above ground in the horizontal arm of an "L" made of 1½" pipe, which will be driven 4 ft. into the ground.



From the gage, 1000 ft. of telcon cable will extend to the field amplifier. This cable will be buried in garden hose if the latter is available in order to simplify recovery after the 100 ton shot.

The field amplifier will be in a box hung from springs, in order to avoid microphonic signals due to earth shock. The amplifier might be further protected by a rubber support between the box and the amplifier.

V. Procurement of gages:

Thirty tourmaline gages are on hand. This provides a factor of 1½ to 2 over what is needed to allow for losses. Consequently, the manufacture of quartz gages will be given low priority, but will continue as time allows.

VI. Practice shots at Y;

Some shots of H.E. will be measured at Y as soon as possible, using the set-up that will be used at Trinity with the exception that scope recording will be used because of the shorter time-scale of small charges. This may turn up unforeseen "bugs", and will test the mountings of gages, amplifiers, etc.

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Figure 9. Piezoelectric gauge on mount (from Robert Walker memorandum dated March 27, 1945).

Piezoelectric Gauge Amplifiers

General

According to Walker (1945:10), the field amplifiers were designed by Matthew Sands. Walker notes that Sands worked in the Electronics Group under Darol Froman (Robert L. Walker, personal communication 1996). The amplifiers consisted of an electrical calibration system and an arming relay in an amplifier box, with a battery power supply in a separate unit, connected to the amplifier by a short cable.

Location

Figure 1 indicates seven amplifiers at South 930, 940, 1,110, 1,120, 1,130, 1,300, 1,310, 1,530, and 1,540. As with the gauges themselves, there is no indication of amplifiers on the north alignment.

Figure 1, then, gives the following locations for the gauges and the amplifiers, in terms of yards south from Ground Zero:

Gauge	Amplifier
600	930
610	940
780	1,110
790	1,120
800	1,130
970	1,300
980	1,310
1,200	1,530
1,210	1,540

This is consistent with Walker (1945) in that every gauge and its amplifier are 330 yd, or roughly 1,000 ft apart.

Configuration

Walker (1945:4-5) explains that the amplifiers were shock-mounted in a metal "cabinet" on sponge-rubber supports. Walker (personal communication 1996) notes that this was in fact a box about 12 by 10 by 8 in., which shielded against the earth shock that preceded the air shock. The amplifiers were then housed in sponge-rubber-lined plywood boxes that were hung by four screen-door springs from a pipe A-frame. Walker's recollection (Robert L. Walker, personal communication 1996) is that these were simply unpainted plywood.

Comments/Results

Bainbridge is at odds with Figure 1 in saying that there were 11 gauges. According to Walker (1945), this was the case in the 100-ton test. If we believe Figure 1, however, only 9 gauges were deployed for the atomic test. Dr. Walker states that this was not the case; that there were gauges on both north and south alignments in both tests (Robert L. Walker, personal communication 1996).

Walker left Trinity immediately after the test and could not say whether any of the gauges was recovered, or whether any of the amplifiers survived (Robert L. Walker, personal communication 1996). None of the gauges has been located, but some of the pipe stands may still be on the site.

There is no obvious resolution of the discrepancies presented here as to the number and location of the piezoelectric gauges and amplifiers. In general, the individual reports written just after the test are the most accurate source, but in this case, Walker (1945) refers to the 100-ton test, not the atomic test. I suggest that Figure 1 may be most accurate in this case.

As noted above, the piezoelectric gauges failed in the atomic test and gave no records.

Sources

Bainbridge 1976: 64; Robert L. Walker, personal communication 1996; Walker 1945; Figure 1.

Gamma Sentinels (Type A)

General

There were two types of sentinels employed to observe delayed gamma rays from fission products. The Type A sentinels were photographic materials (film); the Type B were ionization chambers.

As Moon (1945) makes clear, the purpose of the sentinels was to let personnel know the danger level before entering a given area after the explosion.

Location

Figure 1 shows nine Type A gamma sentinels: at South 400, 800, and 1,500; at West 800 and 1,500; at North 400, 800, and 1,500; and at East 1,500.

Configuration

Bainbridge says that

> In addition to the ionization chamber measurements they also made measurements of the total radiation in gamma units at various distances from the bomb and under several amounts of lead shielding, using the blackening of photographic materials. [Bainbridge 1976:53]

Robert R. Wilson (personal communication 1996) believes that the Type A sentinels measured total radiation on photographic plates. He speculates that these were boxes mounted on pipes, shielding small squares of photographic material with various thicknesses of lead, but adds that this is not a specific recollection.

In a memorandum dated April 14, 1945, from M. Deutsch to "All concerned," entitled "Gamma-Ray Yield Measurement at TR by Means of Moving Film," Deutsch says:

> We propose to measure the intensity of delayed gamma radiation from TR shot as a function of time by the blackening of photographic film which is moved past a window in a lead box. These measurements supplement the ionization chamber measurements planned by Group R-4 [that is, the Type B sentinels] by providing additional stations, by being unaffected by electrical disturbances and by being practically certain to survive both earth shock and blast wave, allowing measurements as late as 30-50 seconds. It covers a smaller range of efficiencies than the ionization chambers. The attached sketch shows the tentative design of the device (Figure) [Figure 10]. In order to cover a wider range of intensities, two 16mm movie films are to be moved simultaneously; the radiation has to pass through a filter of 2cm of Au [gold] or U [uranium] to reach the second film. Nearly all of the space not occupied by film or reels will be filled with lead. The film speed planned is about 2 ft/sec.

This preliminary discussion tells us that the sentinel was run by a motor that was either spring or battery operated; we do not know which, since this is not on the drawing. The description also specifies that timing marks would be furnished by a "simple neon-bulb relaxation oscillator." This oscillator is not pictured either, nor is the starting relay for the motor.

Comments/Results

So far as we know, this experiment produced no result.

Sources

Bainbridge 1976:53; Moon 1945; Robert R. Wilson, personal communication 1996.

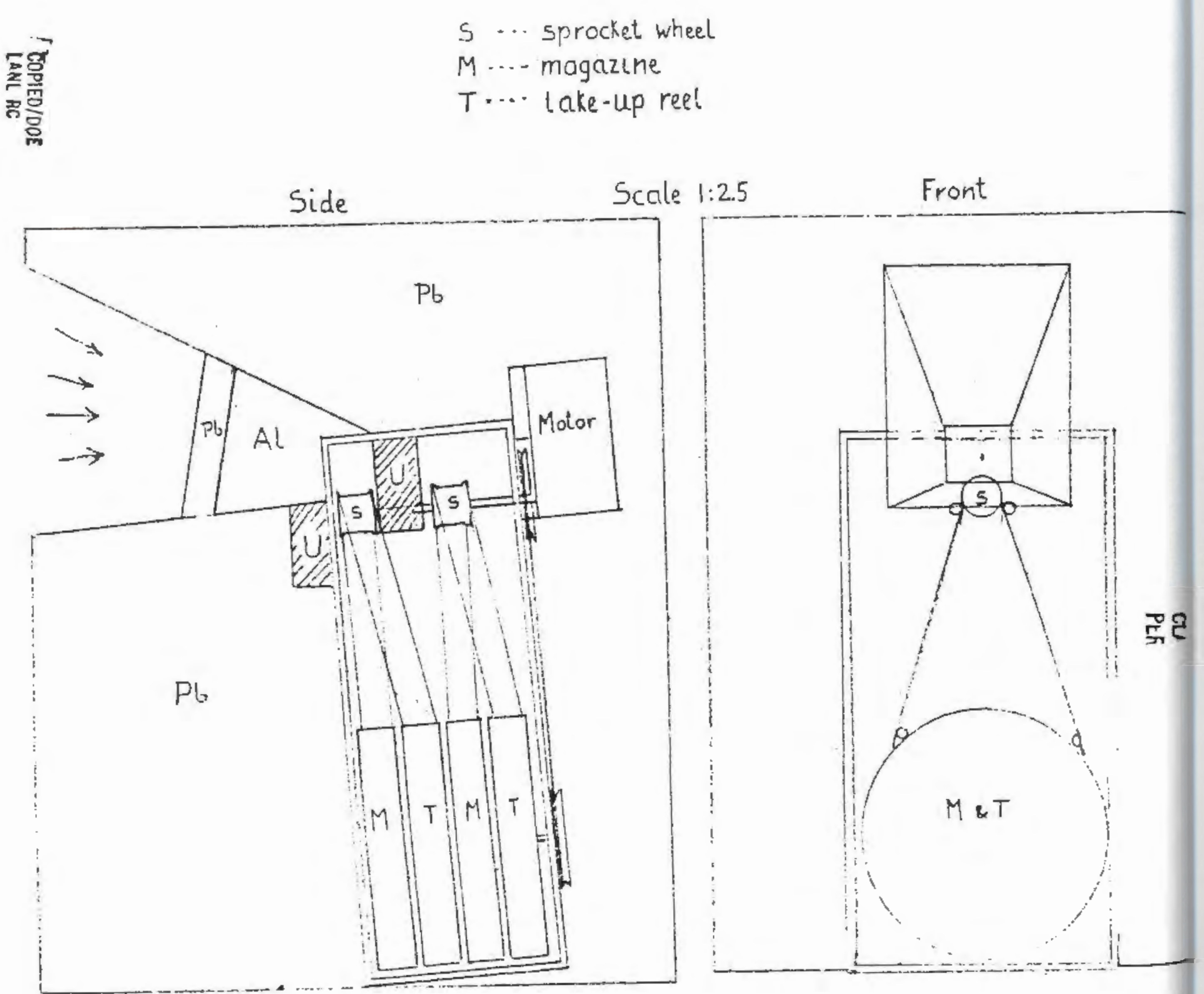

Figure 10. Type A gamma sentinel—moving film camera for measuring delayed gamma radiation (from M. Deutsch memorandum dated April 14, 1945).

Gamma Sentinels (Type B)

General

Bainbridge states that

> The measurement of delayed gamma rays is by ionization chambers, multiple amplifiers, Heiland recorders and ground and balloon sites. [Bainbridge 1976:53]

As with the Type A sentinels, the Type B were for recording ionization levels at a number of points in the area of the test:

> With this information available, an observer proposing to enter the area is forewarned of the hazards that he is likely to meet and can select his time and route of entry accordingly. [Moon 1945:3]

Location

Bainbridge (1976:66) says that there were 16 ionization chambers, which recorded at the 10,000 yd shelters. Figure 2 shows Type B sentinels at South 4,000 and 10,000; West 4,000, 7,000, and 10,000; and North 4,000 and 10,000.

Moon (1945) describes a "network of distant-recording ionization 'sentinels' ..." The report specifies that there were 16 units: five at North 400, 800, 1,500, 4,000 and 10,000, and five at the same distances South; one 1,500 yd east of Ground Zero; and five at West 800, 1,500, 4,000, 7,000 and 10,000. Here, Moon is the most detailed source.

During a reconnaissance on April 29 and 30, 1997, T. Merlan and D. Kirkpatrick relocated several of the shelters described below. These are at North 4,000, West 4,000, West 1,000, North 1,500, South 800, and South 1,500. When the counterweight is still on the site, as is the case at West 1,000, North 1,500, South 800, and South 1,500, its unusual size and shape (8 by 8 by 30 in.) and its smooth, unmarred surfaces (protected by its wooden armature until this fell apart) are a perfect indicator of the Gamma Sentinel B.

Configuration

Moon says that

> The instruments consisted...of an ionization chamber in series with a source of potential difference and an argon discharge tube, the frequency of discharges being a measure of the ionization level. They were battery-driven and recorded their readings automatically within the 10,000-yd shelter. [Moon 1945:2]

The report also notes that the chambers "[had] a volume of the order of a liter" (Moon 1945:3).

A chamber was connected in series with a source of voltage and an argon-discharge tube. At stations closer than 4,000 yd to Ground Zero, the unit rested on a shelf inside a small shelter buried in a hill of sand (Figure 11). The unit was under a heavy steel lid, which worked on a pivot. The lid rose by the action of a counterweight.

> The lid then rose, owing to the action of the counter weight, raising the sentinel unit from its shelf and carrying it into the open air. In leaving the shelf, the unit was switched on by the action of...switch buttons...[Moon 1945:5]

Figure 12 shows the box that contained the sentinel, post-test. Figure 13 shows one of the boxes in 1997.

The units farther away than 4,000 yd were simply contained in plain wooden boxes.

> Each field station was connected by telephone lines (running for most of the distance within rubber-covered cables each containing five pairs) to one of the three main shelters at the 10,000-yd points on the south, north and west roads. [Moon 1945:5]

A paper entitled "Layout and Wiring at Trinity" (n.d., Record Group A-84-019, Box and Folder 54-6, LANL Archives) tells us that five-pair, rubber-covered cable was the wiring used to handle signal circuits from ionization sentinels.

Comments/Results

Moon states that

> ...the 400-yd and 800-yd stations were damaged by the explosion, while those at greater distances survived; the surviving sentinels showed a strong wave of ionization travelling in the northward direction from the explosion point, with comparatively little in other directions...N-400, S-400, S-800, W-800 and S-1,500 were not operable after the explosion. The remaining eleven stations survived in good condition. [Moon 1945:2, 7]

Sources

Bainbridge 1976:47, 53, 63, 66; Moon 1945; TR-438; Figure 2.

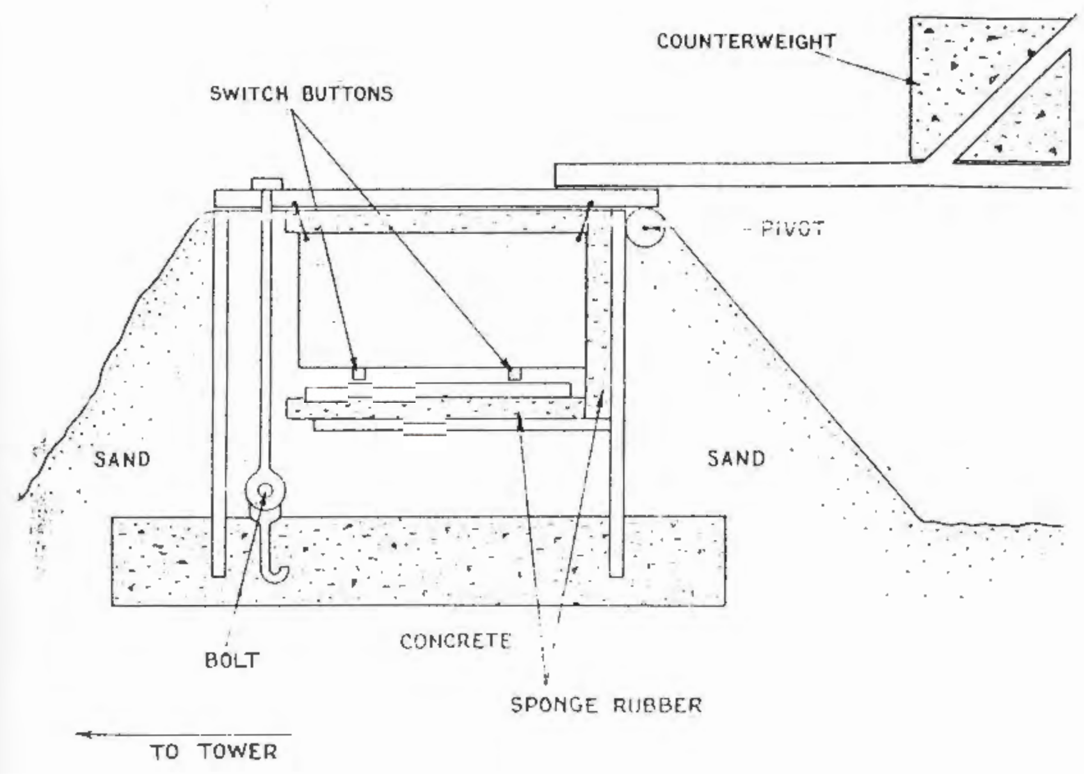

FIG. 4

Figure 11. Type B gamma sentinel (from Moon 1945).

Figure 12. Type B gamma sentinel (TR-418).

Figure 13. Type B gamma sentinel box, 1997.
Note counterweight (photo by Stephen P. Merlan).

Excelsior-Filled Boxes

General

Two woodeu boxes filled with excelsior were placed at each of five stations to test whether the bomb would ignite inflammable materials.

Location

The boxes were placed at 275, 400, 800, 1,600 and 3,200 ft on the West alignment.

Configuration

The boxes were 1 ft square and 6 in. deep. They were filled with excelsior and covered with small mesh-wire netting. At each station the boxes were backed by a mound of dirt and secured to heavy wooden stakes driven into the ground.

Comments/Results

Marley (Marley and Reines 1945a) notes that "the blast from the bomb was somewhat more severe than anticipated." Nothing was recovered from the station at 275 ft. At 400 ft, the boxes were completely destroyed. At 800 ft, they were scorched; at 1,600 ft, they were destroyed and scattered; and at 3,200 ft, they were scorched, but still whole.

Marley and Reines (1945a) contains pictures of the boxes. Some of the stakes to which they were fastened may still be in place.

Sources

Marley and Reines 1945a; not shown on Figure 1.

Geophones and Geophone Amplifiers

General

The geophones (Figures 14 and 15) were devices for transforming ground vibrations into electric signals. They measured ground shock. This experiment could also be used "...for defense against possible law suits for property damage" (Coon and Houghton 1945a:3), or "...as a basis for estimating building damage caused by the earth shock from a gadget set off near the ground" (Coon and Houghton 1945b:3).

The geophones served the same general purpose as did steel stakes to measure permanent displacement of the ground (see below) and seismographs (see below).

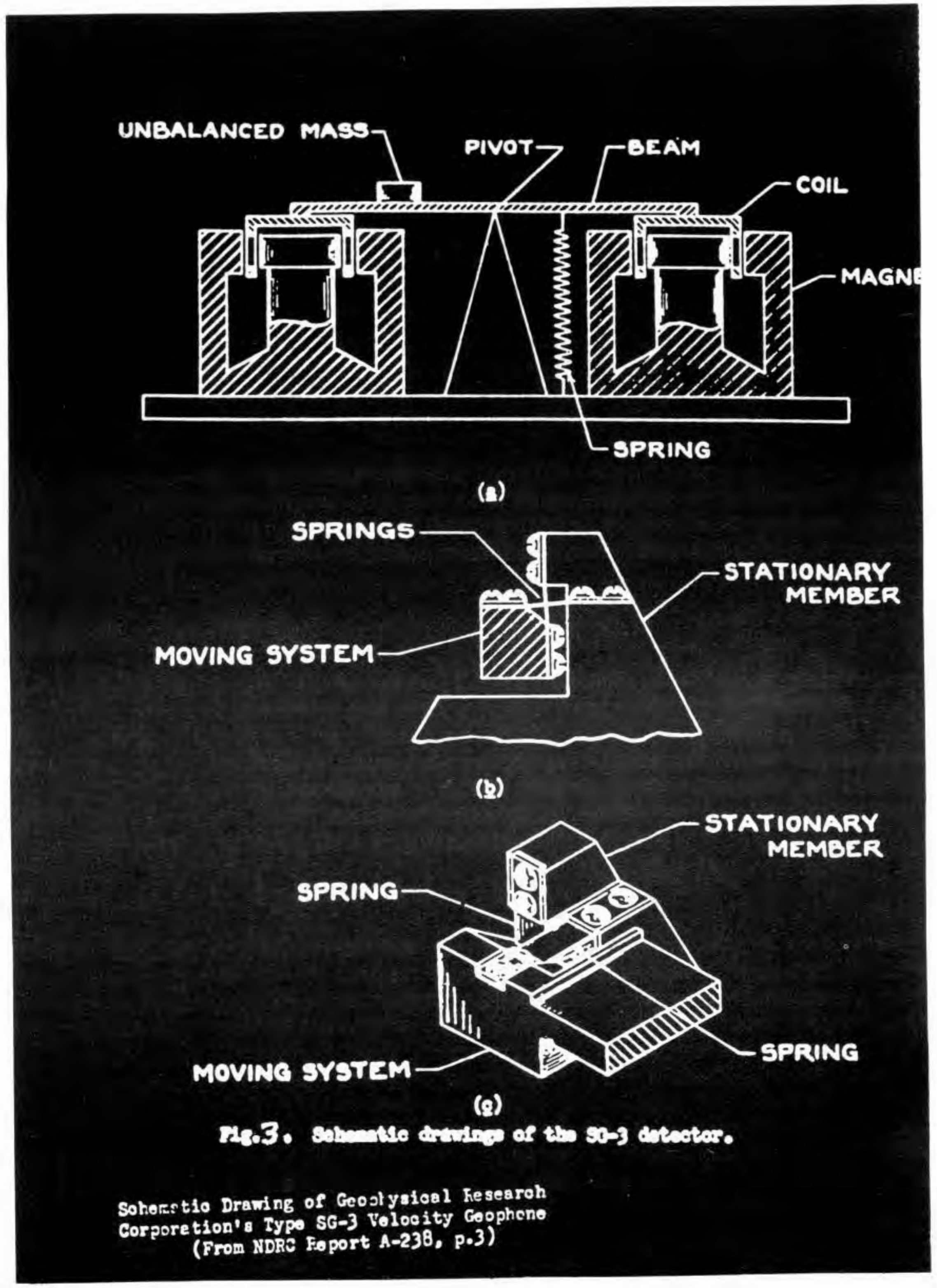

Figure 14. Geophones (from Coon and Houghton 1945a).

Figure 15. Geophones after test (TR-253).

Location

Twelve geophones were planted at distances of 800, 1,500 and 9,000 yd North and South (Coon and Houghton 1945a:6; Figures 1 and 2). As indicated in Figure 1, the geophones are typically 75 yd from the alignment "to minimize noise from that source" (Coon and Houghton 1945a:6). One is 35 yd off the alignment, and one is 200 yd away, to avoid other equipment. Since there are six locations and 12 geophones, we infer that two were placed in each location, as shown in Figure 14.

During a reconnaissance on April 29 and 30, 1997, T. Merlan and D. Kirkpatrick examined the locations of the geophone amplifier pits at North 800 and South 800 (at 75 yd off the alignment, as indicated on Figure 1), but found no trace of them. They probably washed in long ago, during the torrential rains that occasionally sweep over the Tularosa Basin.

Configuration

Two different, but similar types of low-frequency balanced-beam geophones or pickups were used as geophones: Type 810 cathode-follower amplifiers, an alternating-current-operated control box, and a balancing panel. Records were taken by three Heiland Type A-401R 6-trace oscillographs. Four of the geophones were Geophysical Research Corporation Type SG-3, modified to have a longer period, while the remaining eight were modified at Los Alamos to have longer beams.

Figure 16. Geophone amplifiers after test (TR-259).

The amplifiers (Figure 16) and their auxiliary equipment were designed by Matthew Sands and built under his supervision.

The field layout described in Coon and Houghton (1945a) deals with the 100-ton test; the remarks on field layout are then somewhat modified by Coon and Houghton (1945b) on the atomic test. The geophones and amplifiers were planted in pits dug in the ground. The geophone pits were 36 by 12 in. by 24 in. deep and were filled in with loose dirt. The amplifiers and power supplies were mounted in pairs in wooden boxes, which were suspended by springs from a beam across the top of the amplifier chamber. The amplifier cases were metal boxes inside the wooden boxes, which were lined with sponge rubber and felt. The amplifier chambers were closed with a cover of plywood and felt, which then had dirt piled on it. (See Figure 14 for diagrammatic sketches of the geophones and the manner in which they were planted in the ground.) There were two amplifiers at each station. Signals were transmitted along twisted-pair telephone lines to the Heiland recorders at South or North 10,000. For the 100-ton test, the twisted pairs were laid on the ground from the pits to the pole line, and were then carried on knob insulators on the cross arms of the poles (Coon and Houghton 1945a:6). For the nuclear test, the signal wires within 3,000 yd of Ground Zero were laid in shallow trenches; those beyond that point were stretched on poles (Coon and Houghton 1945b:8).

Coon and Houghton (1945b) indicate that during test (scaling) shots, the amplifiers were planted at a distance of 740 ft from their geophones. It is not clear from the report what the configuration was for the nuclear shot. It is arguable that, if the geophones and amplifiers had been separated, the detail location plan would show it, just as it did in the case of the piezoelectric gauges and their amplifiers. However, since there was no particular reason to move the amplifiers for the atomic test, it is more likely that they remained as described in Coon and Houghton 1945a.

Comments/Results

Six of the twelve geophones gave readable records, but "...no records were obtained at several of the close stations because the electromagnetic storm due to the exploding gadget induced large signals which either paralyzed the amplifiers or bent the galvanometer suspensions" (Coon and Houghton 1945b:9).

Coon and Houghton notes that:

> ...the earth-motion measurements corroborate the prevailing opinion that a wider damage radius can be obtained by exploding the gadget in the air to increase the effectiveness of the air blast, than by exploding the gadget on the ground to increase earth shock. [Coon and Houghton 1945b]

Sources

Bainbridge 1976:2, 20, 65, 73; Coon and Houghton 1945a, 1945b; TR-253; Figure 1.

Paper Box Gauges

General

Box-type gauges were used to measure blast pressures as a function of distance from the nuclear explosion.

> Aluminum diaphragm box gauges were among the simplest devices used at Trinity to measure blast pressure....The gauges operated on the principle that the blast pressure would break a diaphragm covering a large opening more easily than one over a small opening. A series of boxes with holes of different sizes covered by the same diaphragms, calibrated, and placed at various distances from Ground Zero, would provide an inexpensive and accurate measure of the pressure. Similar gauges had been used at the Aberdeen Proving Ground by Robert Sachs. The greatest difficulty with these gauges was finding uniform diaphragms to cover the holes. Metal foil proved to be the most uniform thin covering. [Hoddesen et al. 1993:360]

A memorandum dated March 19, 1945, from J. H. Manley to K. T. Bainbridge refers to experiments with various materials for the diaphragms. First paper, then cellophane was proposed and rejected. Metal (aluminum) foils had been decided on as of the memo (Record Group A-84-019, Box and Folder 53-12, LANL Archives).

There were twelve holes in eacb gauge, with diameters of 3 1/2, 2 1/2, 1 7/8, 1 7/16, 1 1/8, 15/16, 13/16, 11/16, 5/8, 9/16, 1/2, and 7/16 inch (Memorandum by J. C. Hoogterp, 4-16-15, Record Group A-84-019, Box 53 and Folder 53-14, LANL Archives).

Location

The box gauges were set up on four radii: West, North, East, and Southeast.

Although *Trinity at Fifty* (Mendez et al. 1996) purports to identify the remains of several paper box gauges (i.e., see Figure 4, pg. 29), this identification was offered before any details of the construction of the gauges was known. T. Merlan and D. Kirkpatrick reexamined these locations on April 29 and 30, 1997. The poles and lathes at the locations may be communications line Ts and braces. None of the paper box gauges has been unmistakably identified on the site.

Configuration

The paper box gauge was a "bursting-diaphragm type of peak-pressure gauge" (Hoogterp 1945:2). Aluminum foils covering holes of different diameter were used as indicators of the magnitude of peak pressure occurring in the 100-ton and Trinity tests.

The foils were mounted over the front of a wooden box of

> ...one-half-incb plywood with joints having an airtight seal. The partitions were quarter-inch plywood. Two pieces of quarter-inch masonite drilled with appropriate hole sizes and with a thirty-second inch neoprene gasket between, made up the foil plate. The gasket was cemented to the outer plate. Each foil was firmly clamped in position by an arrangement of machine screws and wing-nuts about the individual holes. Wood screws held the plate to the box. [Hoogterp 1945:8]

The boxes were mounted on wooden packing crates for the 100-ton test, while for Trinity the boxes were mounted on 4-by-4-in. posts between 5 and 6 ft high (Hoogterp 1945:9) (Figure 17). Hoogterp could be mistaken here; tbe photograph appears to show 2-by-4-in. posts.

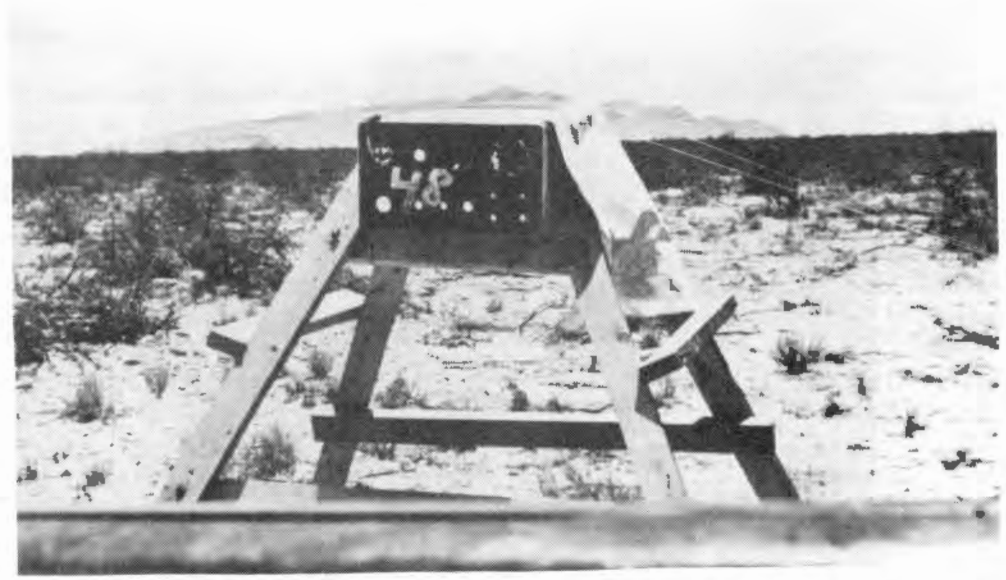

Figure 17. Paper box gauge after test (photo by J. Carlton Hoogterp).

Comments/Results

The detail location plans show 52 gauges, and Graves also says there were 52. However, Bainbridge (1976:11) says there were 29.

The box gauges measured the yield at 9,900 ± 1,000 tons of TNT (Bainbridge 1976:68). This was low by about a factor of two.

Sources

Bainbridge 1976:2, 64, 68; Graves and Hoogterp 1945; Hawkins 1983:244; Hoogterp 1945, personal communication 1996.

Flash Bombs

General

"Forty-seven flash bombs to be operated by arrival of the blast were installed" (Bainbridge 1976:11). See Figures 18 and 19.

Location

Bainbridge's statement that there were 47 flash bombs agrees with Figures 1 and 2. However, Edwin N. York (personal communication 1997) states that there were 12 (six pairs), located about 6 mi north and east of Ground Zero, since this was the expected wind direction from Zero, and the object was to place the flash bombs where they would be under the cloud when it passed over. York states that all six pairs were in one general area, at distances from one another of about 200 ft. Note, however, that Figure 1 does not show any flash bombs in this area.

Figure 18. Flash bomb (TR-296; photo by Edwin N. York).

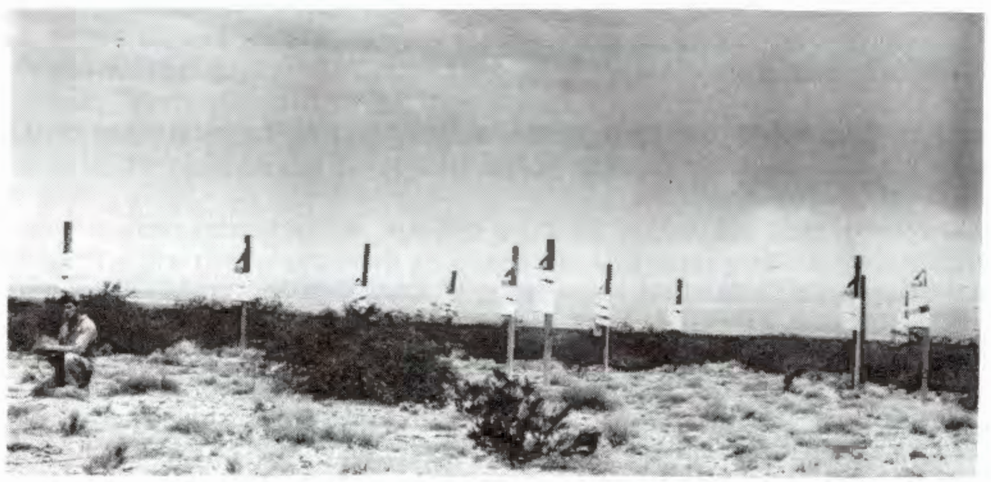

Figure 19. Flash bomb array (TR-329; photo by Edwin N. York).

Configuration

York (personal communication 1997) states that there were 12 flash bombs mounted on six pairs of posts joined by crosspieces (two flash bombs on each). However, both TR-296 and TR-329 appear to show single flash bombs. It is possible that both single and double configurations were used.

York (personal communication 1997) explained that each flash bomb was a light bomb casing containing 100 lbs of flash powder. These were obtained from the Army Air Corps; York does not recall what installation they were shipped from, but states that he saw them arrive in Army trucks. He explained that in normal use a flash bomb was dropped from an airplane and detonated by a timed fuse. They were used extensively for night photography. These were the biggest flash bombs known to the Trinity scientists. Civilian Felix Geiger designed flashers (TR-332). These were set on the ground between two 4-by-4-in. posts; the flash bomb was taped above the flasher on a horizontal crosspiece about 4 ft above the reflector.

York also stated that the flash bombs were set up because there was no assurance that the cloud would illuminate itself. He said further that the flash bombs were timed to detonate at two-minute intervals, but that only two pairs actually detonated, at 2 minutes and 4 minutes from the atomic explosion.

Comments/Results

York (personal communication 1997) comments that the test worked, but was unnecessary, because the cloud remained luminous.

York also states that after the atomic test, he recovered the flash bombs, emptied the powder from those that had remained unexploded, and detonated the powder.

Sources

Bainbridge 1976:11; TR-296, TR-329, TR-332, TR-334; Edwin N. York, personal communication 1997.

Torpex Charges

Location

These shock switches and Torpex charges are not on Figure 1. According to Benjamin (personal communication 1997), there was a single line of tripods. A tripod was set up within perhaps 100 yd of Ground Zero; additional tripods at diminishing intervals were set up on a north-south alignment between Ground Zero and South 10,000. There were "fewer than twenty" tripods (B. C. Benjamin, personal communication 1997).

A memorandum dated May 18, 1945, from J. E. Mack to John Williams (Record Group A-84-019, Box and Folder 54-15, LANL Archives) says that there were 48 shock switch stations. It was proposed to spring mount them on 3/4-in. pipe tripods. The stations, according to this memo, were to be on eight radii from Ground Zero on each of six specified azimuths.

We conclude that not all the stations were actually built.

General

Torpex is a castable explosive mixture of RDX, TNT, and aluminum. This experiment was among those designed as alternatives to electronic experiments that might fail due to electromagnetic disturbances caused by the blast. Julian Mack requested the construction of a switch that would close a circuit when hit by the shock wave of the blast. The experiment was built and tested in Los Alamos (B. C. Benjamin, personal communication 1997).

Configuration

Benjamin (personal communication 1997) states that the shock switches, which he and George Economou set up (TR-158), were designed to activate Torpex charges when the blast pressure set them off. Each Torpex charge was taped to the top of its tripod with duct tape. See Figure 20 (TR-391A) and Figure 21 (enlargement of TR-300).

The charges were to be photographed by Julian Mack's cameras at West 10,000. These were 35 mm cameras in which the film was marked to record the periodicity of the explosion of the Torpex charges. A battery of four cameras was mounted on a salvaged bomber gun turret (TR-201).

"A battery on the ground and a detonator that would detonate the Torpex completed the assembly. The Torpex was a flash bulb that we could see with our cameras" [from West 10,000] (B. C. Benjamin, personal communication 1996). Benjamin had tripods made of "ordinary pipe" built in the shop. He used metal springs to mount the shock switches. The shock switch was a piece of copper foil mounted in the front of a can-like housing. In the back of this housing was an adjustable electrode in the form of a brass rod that came within a few thousandths of an inch of the copper foil. The copper foil, in recoiling from the shock wave, would make contact with the rod, or electrode, behind it.

A circuit connected the battery and the detonator.

Comments/Results

Benjamin (personal communication 1996) notes that the thermal radiation from the explosion caused the failure both of the Torpex charge and primacord experiments by causing them to activate prematurely. He states that he and J. E. Mack were at West 10,000, on top of the camera shelter, during the test. The film itself was blackened by excessive light and showed nothing. All the tripods and the equipment on and around them were blown away by the force of the blast. Nothing of this experiment was recovered.

Figure 20. George A. Economou and Benjamin C. Benjamin (with hat) setting up Torpex charge tripod (TR-391A).

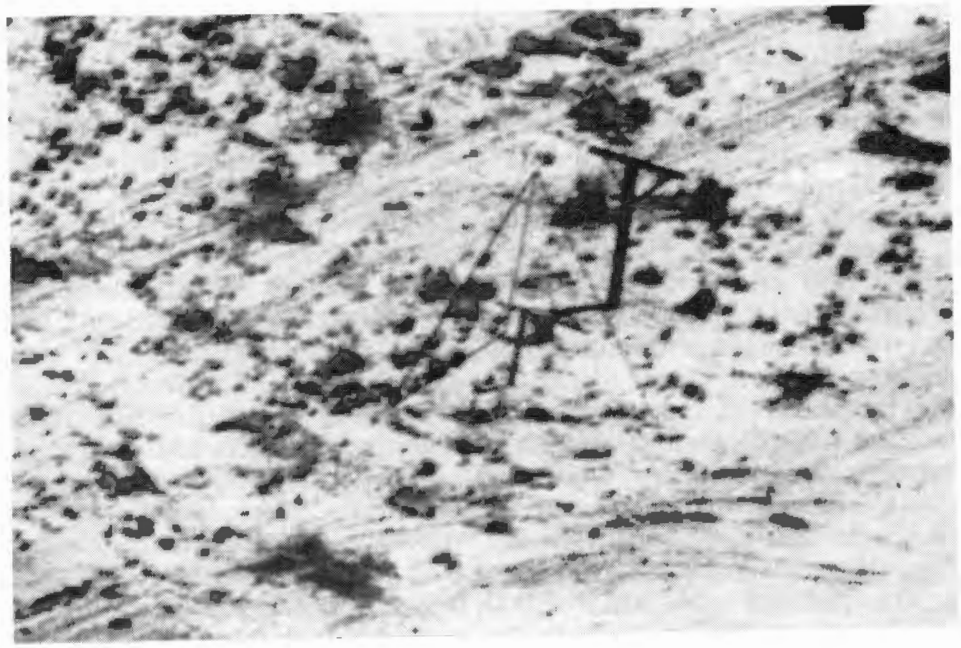

Figure 21. Torpex charge tripod (enlargement from TR-300).

Sources

Benjamin C. Benjamin, personal communication 1997; TR-158, TR-391A and B.

R4 Ground Station and R4 Balloon Winch

General

Bainbridge (1976:47) notes that, "E. Segrè and others attempted to measure the time dependence of the gamma radiation at two stations with ionization chambers."

Segrè, in a memorandum dated March 21, 1945 (Record Group A-84-019, Box and Folder 53-16, LANL Archives), puts it that "we have been assigned the problem of finding out by measurements of gamma activity the number of fissions occurring in the Trinity explosion...we will try to measure the ionization produced by the gamma rays as a fmction of time from the time of the explosion up to the time in which the ground wave or possibly the shock wave will reach the stations of observation."

Location

Figure 1 shows the ground station at 600 west-northwest and the balloon winch at 450 west-northwest. Bainbridge appears to average these distances in his remarks below. However, Aeby (personal communication 1997) suggests that the ground station was a pair of ionization chamber detectors on the ground, while the barrage balloons carried another set (see below).

Configuration

Bainbridge (1976:53) states:

> There were two stations for ionization chambers, one on the ground at 550 m. from the bomb and another at the same distance but lifted by a balloon to an elevation such that the line joining the balloon with the bomb made a 45° angle with the horizontal.

Segrè is pictured in Fermi and Samra (1995:132) standing in front of a barrage balloon used in this experiment (Figure 22).

In a memorandum dated March 21, 1945 (Record Group A-84-019, Box and Folder 53-16, LANL Archives), to Bainbridge, Fermi, Moon, and Wilson, Segrè says that Group R-4 will try to measure the ionization produced by the gamma rays as a function of time from the time of the explosion up to the time in which the ground wave or shock wave will reach the observation stations. He planned three observation stations at 2,000, 2,000, and 4,000 ft from Ground Zero. The planned stations at 2,000 ft could be the ground station and balloon-borne station as built; the station at 4,000 ft may also have been built. Aeby (personal communication 1997) states that several stations were actually established. A pair of ionization chamber detectors, encased

Figure 22. Emilio Segrè standing by weather balloon. Note earth anchor (photo by Jack Aeby, courtesy of Los Alamos Historical Society).

in a 55-gallon drum, was flown from a station at approximately 450 yd northwest of Ground Zero (see Figure 1 and Figure 23). A test showed that a single barrage balloon would not support the apparatus, so it was suspended beneath two balloons flown in tandem (Figure 24). The detectors protruded from the drum; the recording equipment was inside it. The balloons were flown at heights of about 150 to 200 ft. The drum hung down on a steel cable to a height of approximately 100 ft; that is, horizontal to the bomb on its tower. The support cable for the balloons was a woven steel cable; the shielded twisted-pair communications cable that transmitted the information was wrapped around the support cable (Jack W. Aeby, personal communication 1997). Another pair of detectors stood on the roof of the bunker at Northwest 600, on two metal pipes that are still in place. Aeby also believes that there were "a few open-air detectors" (Jack W. Aeby, personal communication 1997). He adds that the detectors on the roof of Northwest 600 were not encased in a drum, but were exposed in a line-of-sight to Ground Zero (Figures 25 and 26).

Figure 23. Weather balloons on the ground at Northwest 450—Segrè experiment. This is pretest, but as the caption indicates, it is just beyond the lip of the crater caused by the test (photographer unknown; photograph courtesy of Felix DePaula).

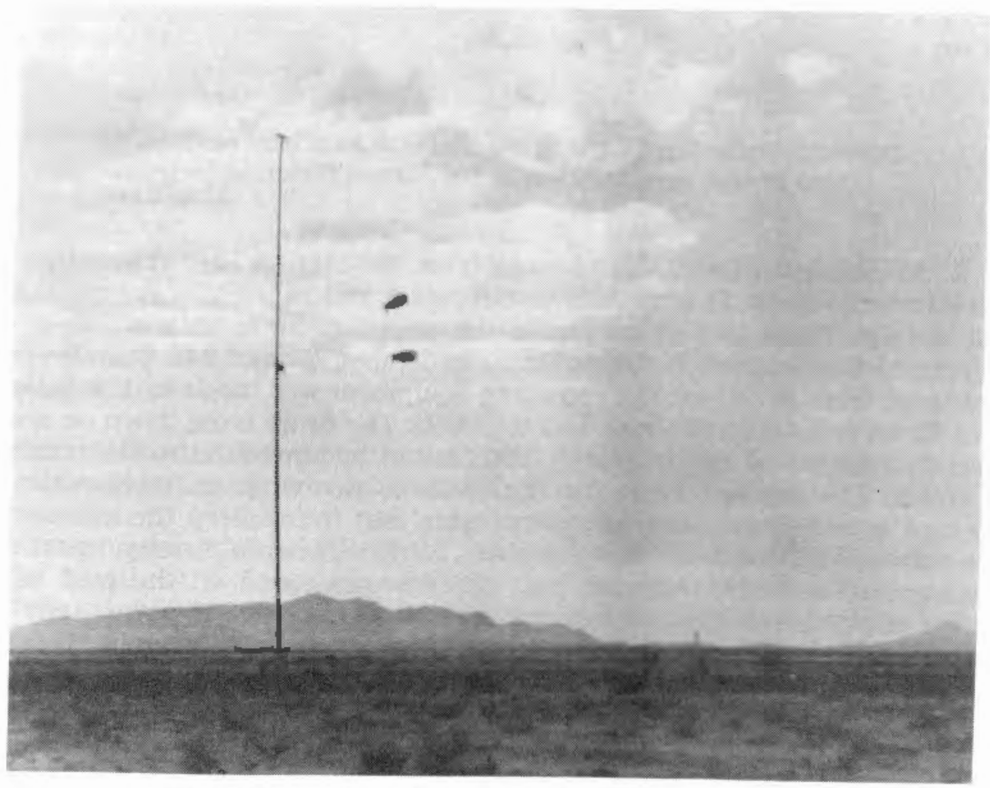

Figure 24. Weather balloons in tandem—Segrè experiment (photograph by Jack Aeby, courtesy of Los Alamos Historical Society).

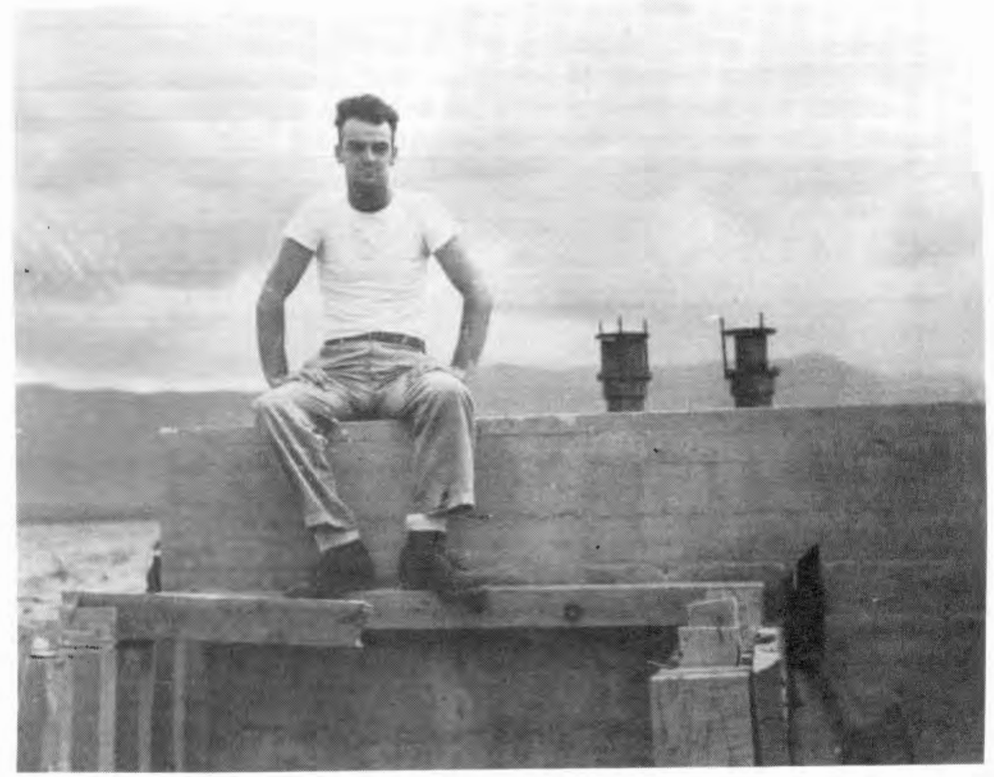

Figure 25. John Miskel, chemist who worked in R-4 (Segrè group) at Northwest 600, July 16, 1945 (photo by Jack Aeby, courtesy of Los Alamos Historical Society).

Figure 26. Robert J. Burton, White Sands Missile Range Archaeologist, at Northwest 600, July 21, 1997 (photo by Stephen P. Merlan).

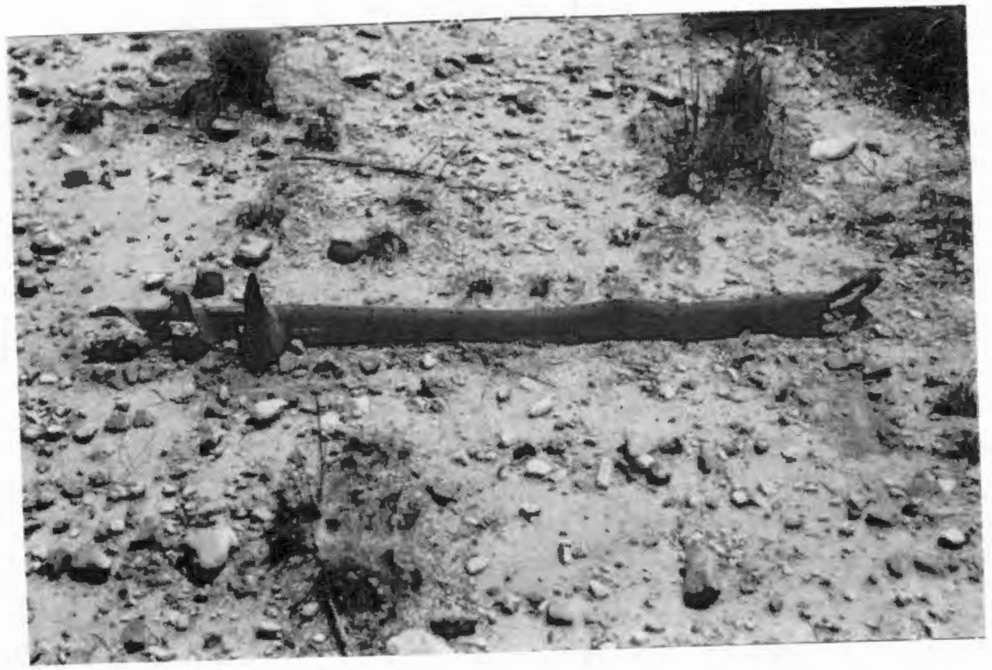

Figure 27. Earth anchor at Northwest 450, site of Segrè's barrage balloons, 1997 (photo by Stephen P. Merlan).

In a reconnaissance on July 21, 1997, T. Merlan, S. Merlan, and R. Burton located an earth anchor at Northwest 450, where Figure 1 shows the balloon site (Figure 27).

The memorandum dated March 21 states that each station consists of two ionization chambers, each with two resistors feeding two amplifiers, which in turn actuate four Heiland galvanometers recording on paper. All the apparatus, except for the ionization chambers, would be enclosed in a steel cylinder, including automatic calibrating devices to be actuated from "the central observation point at 10,000 yards [South 10,000]." According to Aeby (personal communication 1997), there was one pair of airborne detectors and one pair of detectors at Northwest 600. Aeby adds that the Northwest 600 bunker was devoted exclusively to recording equipment for this experiment. Although another source (Hoddesen et al. 1993:377) states that there was a cellophane catcher camera in the Northwest 600 bunker, Aeby does not remember this. He adds that the recorder at Northwest 600 was an Esterlein-Angus galvanometer, while the Heiland galvanometers were probably used in the balloon-borne experiment.

Comments/Results

The memorandum cited above noted that the Heiland oscillographs would be retrieved after the test.

> One [ionization chamber], on the ground at 550 m. gave a result; the other instrument was destroyed by thermal radiation. Their instruments were designed for a lower yield than was obtained, and thus, they got saturation for early times. For later times, 10 to 20 sec, they got significant readings. [Bainbridge 1976:47]

According to Hoddesen and others (1993:375), the airborne meter, unprotected by the ground, was destroyed before it could transmit to the recorders. Hoddesen states that the ground chamber fared better, but the great amount of radiation overloaded the meters in the first few seconds. Still, from about 10 to 20 sec after the blast, Segrè's team obtained reliable readings (Hoddesen et al. 1993:375). However, Aeby observes that the data from the airborne detector may have been telemetered either to a command post or to the Northwest 600 bunker before the ionization chamber detector was destroyed.

Sources

Jack W. Aeby, personal communication 1997; Bainbridge 1976:47; Fermi and Samra 1995:132; Figure 1.

EDG

General

Four units or experiments are shown on Figure 1.

Location

Two of the units are at 100 yd close to true north and 100 yd south, and two are at 200 yd, one close to true north and the other south.

Configuration

The location plan tells us that P. B. Moon was in charge of this experiment.

Bainbridge (1976:65) says that Moon photographed the ball of fire with two gamma-ray cameras; that he was in charge of 16 ionization chambers that recorded at the 10,000 yd shelters; and that he made a detailed crater survey after the shot with ionization chambers and Watts-type amplifiers.

We have not interviewed anyone who recognizes or can explain this designation. Edwin N. York (personal communication 1997) thinks it may mean "Edgerton"—referring to the camera expert of that name who came to Trinity from the Massachusetts Institute of Technology and subsequently was a partner in the firm of Edgerton, Grimmelshausen, and Greer.

Bainbridge (1976:5) says that earth samples were obtained "in the early stages of preparation" before the test.

Barschall (personal communication 1996) speculates that "g" means gauge. The close proximity to Ground Zero suggests either a simple artifact or an experiment undertaken before the test, since any more elaborate equipment could be expected to suffer damage. Robert D. Krohn (personal communication 1996) speculates that Moon would not have built an elaborate experiment. The author guesses that an "EDG" could be an earth displacement gauge.

Sources

Figure 1.

Mack Slit Cameras

Location

Figure 1 shows two slit cameras at 275 yd North and West, at 75 ft off the alignment in each location. A memorandum dated May 18, 1945, from J. E. Mack to John Williams and others (Record Group A-84-019, Box and Folder 54-15, LANL Archives), refers to these locations.

Configuration

A memorandum dated April 13, 1945, from J. E. Mack to K. T. Bainbridge (Record Group A-84-019, Box and Folder 55-16, LANL Archives), describes a "moving film slit camera for gamma ray measurements." Mack says that

> Aside from lead shielding, the instrument consists primarily of two parts: an aperture, which is of an x-shaped space in a plate of tuballoy sandwiched between two solid plates of tuballoy; and a mechanism for moving a film normally across the plane of the aperture. Films move at several speeds, so that in spite of the strong time dependence of source strength and source distribution, one film can always be correctly exposed. It appears practical to utilize three film speeds of the order of 10, 1 and 1/10 meters per second....From intensity estimates it appears that the fastest of these films would yield useful information only if the shot should go on the order of 10 4 T, and then only during the early stages of the expansion of the ball of fire....The instrument is its own self-contained recorder....The film chamber requires a shield of about 6" of lead in front and about 4" on all the other faces....A starting signal will be required...to release the film-moving mechanism. We hope that the film feed can be accomplished mechanically. If not, we will use small Willard plastic storage batteries...

This memorandum includes a sketch (Figure 28).

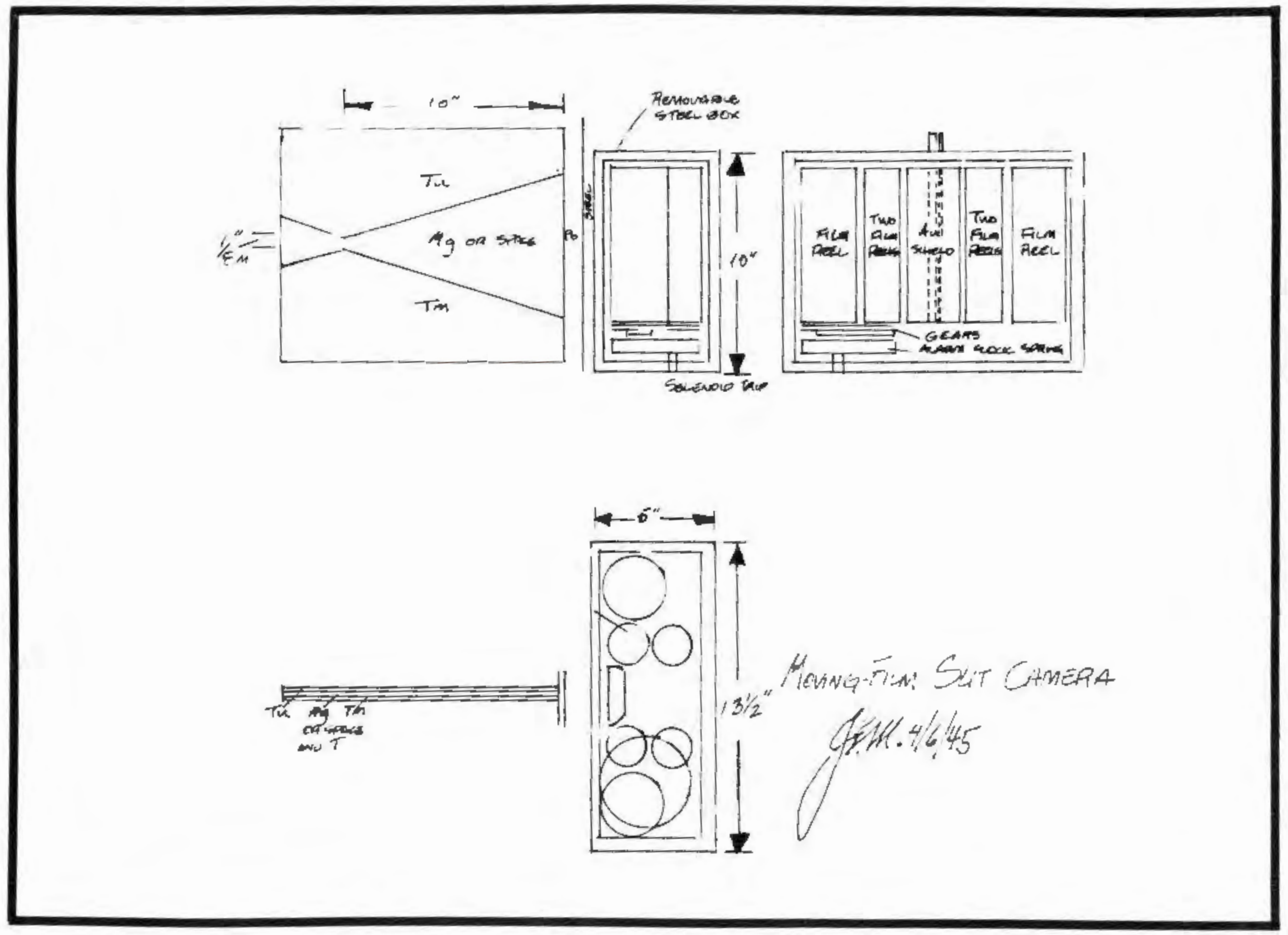

Figure 28. Sketch of moving film slit camera for gamma ray measurements (from memorandum by J. E. Mack dated April 13, 1945).

Jack W. Aeby (personal communication 1997) describes a slit camera that uses light, not gamma rays, to take pictures. However, the author believes, based on the given locations and on Mack's description, that the reference here is to gamma-ray cameras.

Comments/Results

We do not know for certain what the results were. It is likely that the cameras succeeded only in capturing heavy radiation-fogging, as did the pinhole cameras (see below).

Sources

Memorandum dated April 13, 1945, from J. E. Mack to K. T. Bainbridge (Record Group A-84-019, Box and Folder 55-17, LANL Archives); Figure 1.

Pinhole Cameras

General

A memorandum dated April 7, 1945 from J. E. Mack to K. T. Bainbridge (Record Group A-84-019, Box and Folder 53-16, LANL Archives) explains that a simple pinhole camera and a moving-film slit camera are both types of gamma-ray pinhole cameras. Mack considers a simple pinhole camera marginal in terms of time resolution, and the two cameras about equal for the purpose of angular resolution.

Bainbridge (1976:65) states that P. B. Moon was in charge of two gamma-ray cameras for photographing the ball of fire.

Location

Halpern and Moon (1945:3) state that "stations were established at 150 yds and 275 yds to the south of 'O'..."

Configuration

Halpern and Moon note tbat

> ...apparatus was constructed in which a gamma-ray image [also referred to as a 'gamma-ray pinhole image'] of the 'ball of fire' was projected on a fluorescent screen through a small aperture in a block of lead....[Halpern 1945:2]

The pinhole cameras were cameras of high resolving power, with small fields of vision. They captured gamma rays emitted by the blast and used these to take a picture. They were about 2.5 ft long and 1 ft in diameter at the rear, where the film was located, and tapered to about 6 in. diameter in front. The pinhole was a tapered channel of lead, .3 mm in diameter at its narrowest point. They needed no shutters, since the captured gamma rays were much brighter than any other radiation subsequently seen by them.

A memorandum dated April 14, 1945 from O. R. Frisch to K. T. Bainbridge (Record Group A-84-019, Box and Folder 55-16, LANL Archives), notes that these cameras were to be cast from lead. They would be so heavy that they would need to be transported on a 6-ton truck and loaded and unloaded with a crane.

Buried motion picture cameras were supposed to take optical pictures of the screens. There were two Bell and Howell 16-mm motion picture cameras at a station 275 yd south of Ground Zero. There was a multilens rotating aperture camera at 150 yd south of Ground Zero (Halpern and Moon 1945:38).

Comments/Results

The pinhole cameras and camera stations are not shown on Figure 1, but Halpern leaves no doubt that they were there.

Halpern concludes that

> This attempt to photograph the ball of fire resulted only in heavy radiation-fogging...more than 100 times more intense than what had been predicted...[Halpern and Moon 1945:2]

Sources

Bainbridge 1976:65; Halpern and Moon 1945; Record Group A-84-019, Box and Folder 53-16 and 55-16, LANL Archives.

Impulse Meters

General

Like the paper box gauges and condenser gauges, the mechanical impulse meters or impulse gauges (Figures 29 and 30) were used to avoid electrical disturbances (Jorgensen 1945a:3).

Location

Bainbridge (1976:11) says that five instruments were planned and "one was satisfactorily installed." Bainbridge may be in error here; Jorgensen (1945a) states that one gauge was set up for the 100-ton test, while Figures 1 and 2 show impulse meters at West 350, 520, 600, 720, 1,100, 2,000, and 4,000. Jorgensen (1945h:5) states that there was one meter at 350 yd, one at 520 yd, and two each at 600, 900, 1,000, 1,200, and 2,000 West—twelve in all. TR-266 (Figure 31) shows a stack of four gauges recovered after the test. No source fully agrees here with any other.

Configuration

The gauge was a squirt-gun-type gauge. The mechanism "measured the rate at which water flowed through a tube as a function of time" (Jorgensen 1945b:3). The gauge was

Figure 29. Impulse meter and stand before the test (TR-258).

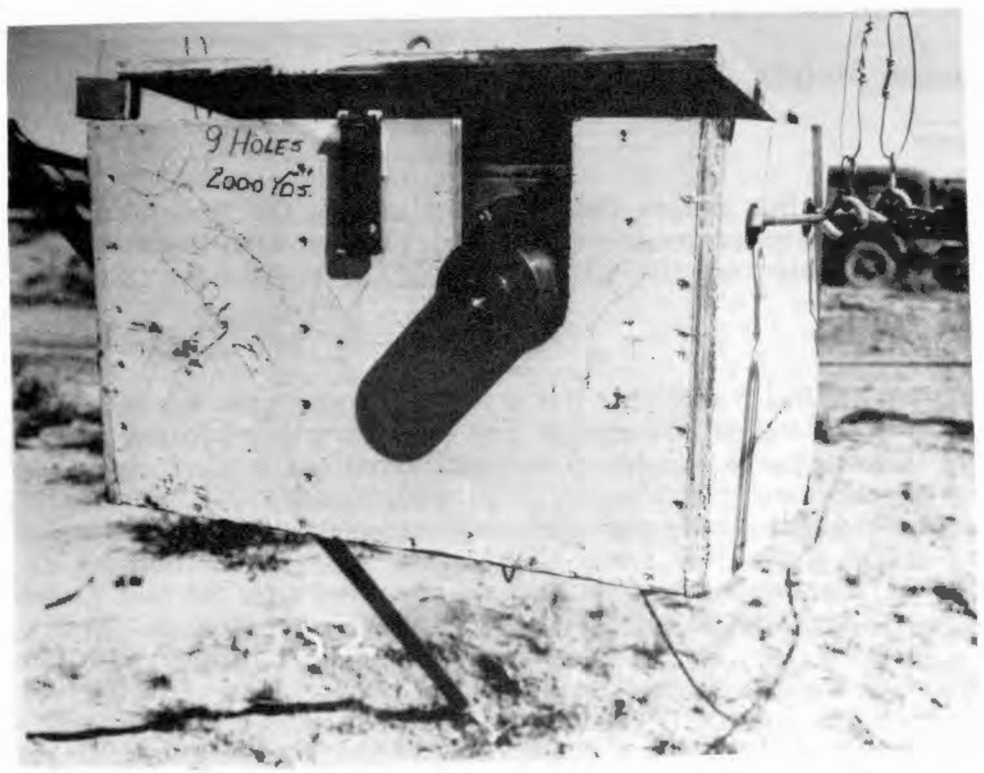

Figure 30. The same impulse meter, close view (TR-252). Note the jocose reference to golf.

Figure 31. Impulse meters recovered after test (TR-266).

...a cylinder filled with water, with a piston at one end and a plate with holes at the other. The position of the piston is indicated by a rod from the piston through the plate with holes. The rod carries a stylus, which marks a rotating smoked-glass disc. The cylinder is mounted on the side of an air-tight dural box and a motor carrying the glass disc is mounted in the box.... The glass discs were rotated by motors powered by a six-volt storage battery. The motors were windshield-wiper motors remodelled to give a speed of rotation of about one revolution per second....The motors and counting circuit were turned on by means of a control line and relays....The dural boxes containing the piston and cylinder, the glass disc, the motor, and the relays were mounted along with the batteries and message register in a plywood box. The box of 3/4" plywood was then supported by screen-door springs on a 1 1/4" iron pipe frame. [Jorgensen 1945b:3-6; see Figure 29]

The third mechanical gauge [that is, along with the condenser gauges and paper box gauges] was a water-filled tube connected to a piston. The water flowed out of the tube when the blast wave created a pressure difference between the ends

> of tbe tube. A stylus connected to the piston made scratches on a smoked glass disk, thus recording the flow rate. Knowing the flow rate, scientists could calculate the peak pressure, impulse, and duration of the positive phase of the blast. Theodore Jorgensen prepared a number of these gauges and placed twelve of them 350 to 2,000 yds from Ground Zero. [Hoddesen et al. 1993:360]

Jorgensen (1945b:6) notes that after the test, eight gauges were recovered practically undamaged, one gauge closest to the explosion was not recovered, and three were recovered in a damaged condition.

Comments/Results

> The water-filled pistons...did not work well. Jorgensen and Ruby Sherr found that they had functioned properly for only a small range of impulses....Eight of the twelve pistons were recovered, bnt only four gave a record of the blast, and only one gave a reasonable result of about 10,000 tons of TNT. [Hoddesen et al. 1993:376]

The impulse gauges were collected and removed after the test, as indicated by TR-266 (Figure 31).

Sources

Bainbridge 1976:11; Jorgensen 1945a, 1945b, 1966:72-74, personal communication 1996; TR-252, 254, 258, 261, 263, 266; Figure 1.

Condenser Gauges

Location

Figure 1 shows three condenser gauges at 1,000 (25 ft from alignment), 1,190 (75 ft from alignment), and 1,400 (25 ft from alignment) West. Figure 2 shows a further five at 1,700, 2,300, 4,000, 6,000, and 10,000 West. Bright (1945:8) states that eight were installed, but only one gave a good record.

> ...condenser gauges were placed at 8 positions west of the bomb tower. The transmitter units were mounted on the 15-foot poles which served as antenna masts. [Bright 1945:8]

Bainbridge states that "eight condenser gauges were planned for use, but only one was installed, and gave no record" (Bainbridge 1976:11). Bright (1945) is probably more to be relied on here than the Bainbridge report.

Configuration

Bright (1945:4) explains that the condenser gauge was a microphone made at the California Institute of Technology. The condenser gauge is diagrammed in Bright's report (1945:Figure 2; see Figure 32).

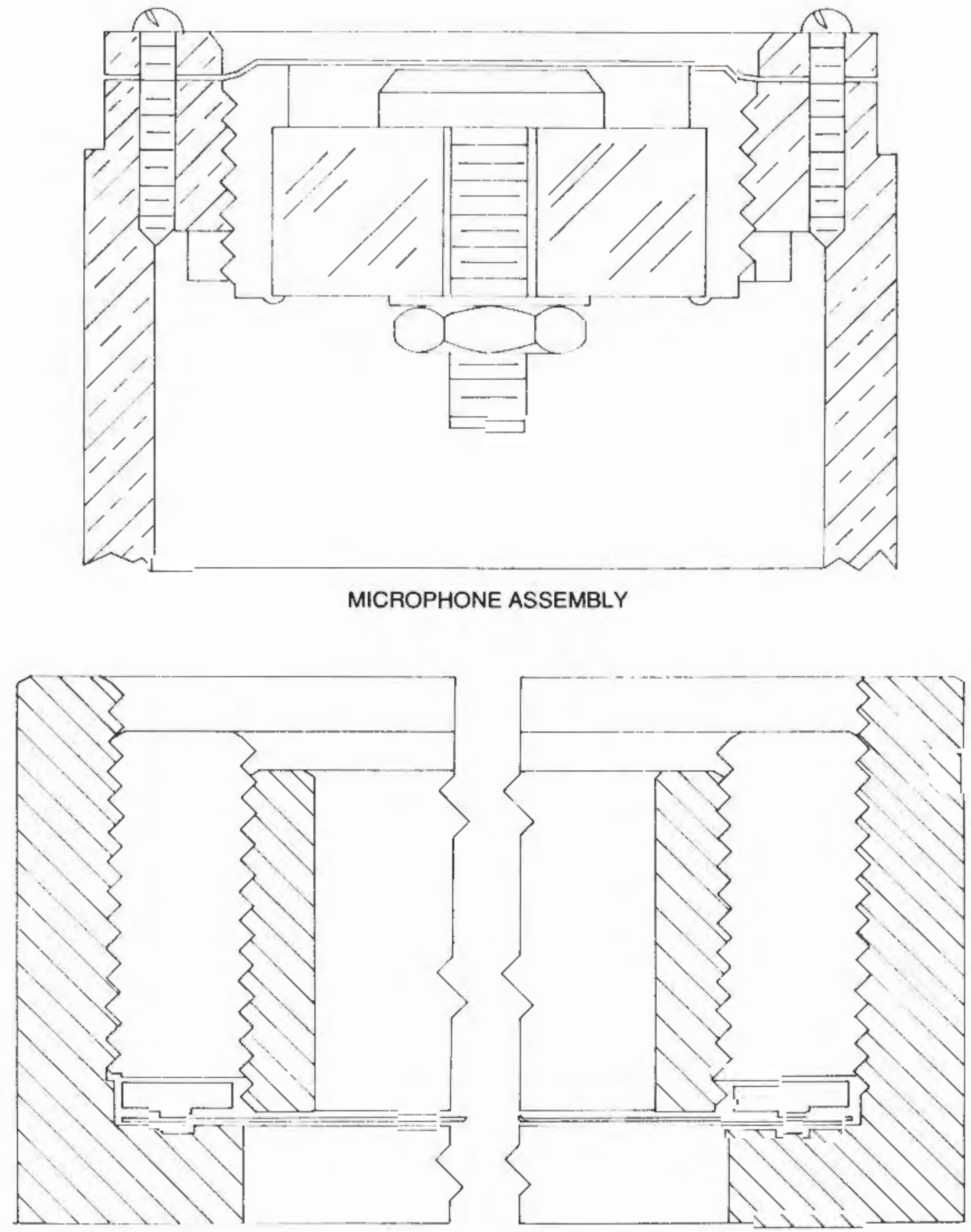

Figure 32. Condenser gauge (from Bright 1945).

Robert D. Krohn (personal communication 1996) describes the condenser gauges as consisting of two plates and an oscillator. An aluminum plate about 3 in. in diameter would bend with the shock of the blast, bringing this plate closer to the backing plate, which would then change the capacity of the condenser. A cable would then take the capacity to a box containing an oscillator. Krohn believes the condensers were mounted on a pipe or stake.

Condenser gauges were also dropped over Trinity from airplanes:

> Three condenser gauges for measuring blast pressure were dropped over the target from a height 15,000 ft above ground by the observation plane...[One of the three] gave an excellent pressure-time record. [Bainbridge 1976:11]

Comments/Results

Hawkins (1983:244) notes that "condenser gauges of the California Institute of Technology type" were dropped from B-29s, but failed to give any readings because the test had to be made when the planes were at a distance.

Hoddesen (Hoddesen et al. 1993:375) has it that Oppenheimer asked Luis Alvarez not to drop condensers over Ground Zero because it would be too dangerous. Alvarez (1987:141-143) also states that they obtained one good record of the blast. Hawkins is evidently mistaken here.

Bright (1945:11) states that one record was obtained from the gauges on the ground, and that this record was accurate for peak pressure to within about 10 percent.

Sources

Bainbridge 1976:11; Bright 1945; Robert D. Krohn, personal communication 1996.

Peak Pressure Gauges

General

There were 20 of these peak-pressure indicators of a "spring-loaded piston type" (Littler 1945:2).

Location

According to Littler (1945), 12 gauges with foil-puncturing indicators were placed at 900 ft, 1,100 ft, 1,300 ft, 1,500 ft, and 1,700 ft West. The other eight gauges were placed at 800 yd (two), 1,000 yd (three), 1,500 yd (two), and one at 2,000 yd West.

Configuration

Littler (1945:3) tells us that in the first 12 gauges, an indicator consisted of six pistons loaded by springs. Each indicator covered a range of pressures.

These gauges were set in 4-by-2-by-3-ft-deep trenches. The gauges were bolted to lengths of channel iron that were set in concrete in the center of the trench.

The other eight gauges were obtained from the Road Research Laboratory in England. In these, the movement of a piston was detected by permanent displacement of a small friction-held rod.

These eight gauges were strapped to the tops of 4-by-4-in. wooden posts. They were insulated against vibration with sponge-rubber pads placed between the gauges and the posts.

Comments/Results

The gauges at the top of the trenches at 900 ft and 1,300 ft and the gauges at 800 yd were blown off their supports by tbe blast. The others gave readings, but the pressures were outside the ranges covered by the gauges, so this experiment failed (Littler 1945:4).

Sources

Littler 1945; not shown on Figure 1.

Excess Velocity Gauges

General

See Figures 33 and 34.

> One of the more sophisticated methods for measuring the blast wave energy was the excess velocity method, which consisted of making a precise measurement of the velocity of sound at the site of the explosion and then comparing it with the velocity of the blast wave. The difference between the two velocities could be used to calculate the energy of the blast. Barschall, G. Martin and others conducted the experiment. [Hoddesen et al. 1993:359]

A memorandum dated March 19, 1945, from Manley to Bainbridge states that the equipment for excess velocity measurement had arrived at Trinity, "but no one knows any technical specifications and it was apparently ordered without knowing if it would be suitable for the job" (Record Group A-84-019, Box and Folder 53-12). He asks for "someone familiar with the equipment to come here for consultation."

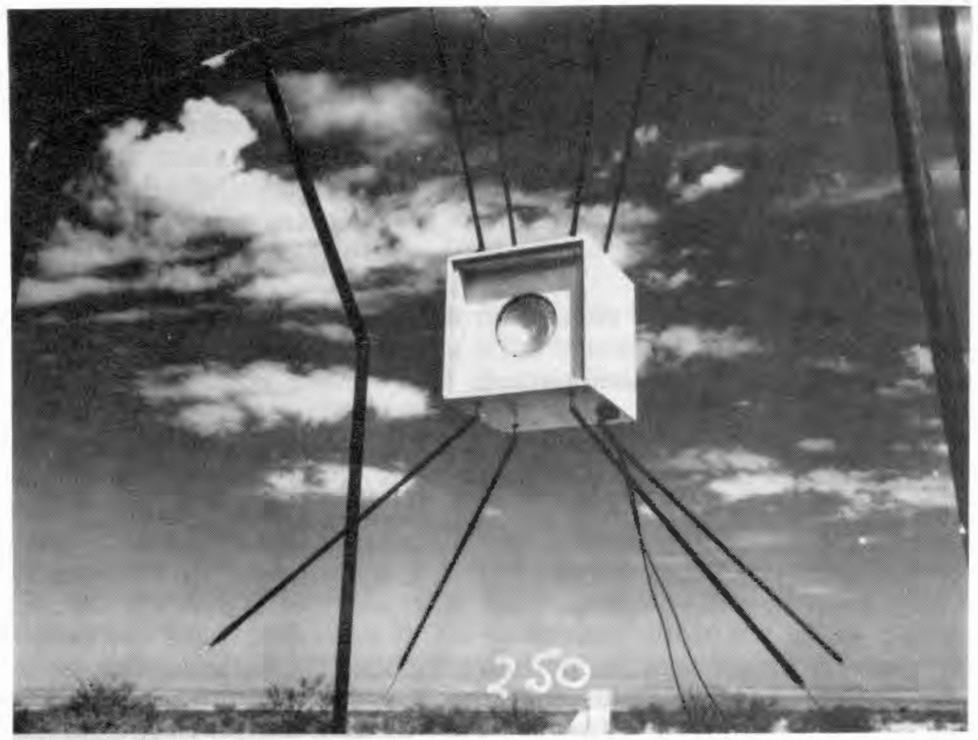

Figure 33. Excess velocity gauge before test (TR-250).

Figure 34. Excess velocity gauge before test (TR-264).

Hawkins (1983:244) says that

> ...the excess shock wave in relation to sound velocity was measured with a moving-coil loudspeaker pickup, by the optical method with blast-operated switches and Torpex flash bombs...by the moving-coil loudspeaker method, the sound velocity was obtained for a small charge and then the excess velocity for the bomb. This measurement indicated a yield of 10,000 tons and was one of the most successful blast-measuring methods.

Location

"Six receivers were installed to pick up the blast wave and record its time of arrival" (Bainbridge 1976:11). Figure 1 shows ten—five north-northwest of Ground Zero and five south-southeast. Barschall (1945b:3) also states that there were ten:

> ...five microphones (north stations) were located on a line through 0 [Ground Zero] at an angle of 15° west of OA. The distance of the stations from O were 400, 500, 700, 1,000 and 1,400 yds. Five more microphones were located at the same distance from 0 and on the same line through 0 on the opposite side from 0 (south stations).
>
> A five-pound charge of pentolite suspended 15 ft above a point 50 yds east of Ground Zero was fired 3 seconds before the nuclear explosion in order to make possible a comparison of the velocity of sound with the velocity of the blast wave.

Configuration

Barschall notes that:

> ...permanent-magnet speakers were used as microphones....The speakers were mounted in plywood boxes padded with felt and open on the side towards Z [Ground Zero]. These boxes were suspended about six ft above the ground by eight springs fastened to iron pipe frames....An audio transformer was mounted in the box with each speaker. The transmission line consisted of a cable containing five twisted pairs of copper wire, and led from the microphones to the [10,000 yd] shelter. [Barschall 1945a]

Barschall (personal communication 1996) adds that the microphones were painted white to retard radiation.

He explains that:

> ...early in 1945 [John] Manley was given the task of performing blast measurements at the first bomb test....None of us had any

experience with such measurements, and we spent much time learning about the new field...while techniques for blast measurements of conventional explosions were well developed, the measurements we were asked to perform had special difficulties. To provide data in the event of a very low explosive yield, our instruments had to be capable of giving results for energy releases differing by a factor of at least 100. Furthermore, the nuclear explosion was expected to produce very strong electromagnetic signals that would disable most electronic equipment, and intense thermal radiation that was likely to burn flammable materials...my assignment was to measure the velocity of propagation of the shock wave as a function of distance from the explosion. The ratio of the velocity of the shock wave to the sound velocity is related to the peak pressure of the shock wave by the Rankine-Hugoniot equation. We used loudspeakers as detectors for the arrival of the shock wave. The motions of the speaker coil in the magnetic field would induce a large signal that could be transmitted to a shelter, where a movie camera would photograph the signal as displayed on an oscilloscope screen. Five loudspeakers were placed in a line at different distances from Ground Zero, so that four average velocities could be measured. Two such strings of speakers were arranged in opposite directions from the tower on which the explosive would be detonated. [Barschall 1987]

The signals from the north microphones were recorded at Shelter A (North 10,000); those from the south microphones at Shelter B (South 10,000). The signals were transmitted over twisted pairs to the recording station. The wires were strung on insulators on a pole line. In the 100-ton test, signals from five microphones were transmitted to one amplifier. In the atomic test, five separate amplifiers were installed. Barschall specified in a memorandum dated June 18, 1945, that the wires should be laid on the pole lines up to a distance of approximately 1,600 yd from Ground Zero, and on the north side they should be buried from there on, leaving about 10 yd at each station on the ground. On the south side he requested that the wires be strung on the ground from the pole line "until they reach the 165° direction except where they cross the tank right of way or the road. If possible, it would be helpful if the wires were in the same order on the ground as on the pole line. The wires should be buried along the 165° line" (Record Group A-84-019, Box and Folder 54-6, LANL Archives).

Barschall's oscilloscope was in North 10,000, where he observed the test. About 20 sec elapsed between the recording of the shock wave by the loudspeakers and the arrival of the wave at North 10,000.

Comments/Results

The excess-velocity blast-yield measurement worked better at Trinity than during the 100-ton test, and provided among the most accurate measurements of the blast pressure (Hoddesen et al. 1993:376).

Sources

Bainbridge 1976:64; Barschall 1945a, 1945b, personal communication 1996; Hawkins 1983:244; Hoddesen et al. 1993:359; TR-250, TR-264.

Tank Rights-of-Way, Range Poles, and Flag Poles

General

See Figures 35 and 36.

Two tanks with openings in the floors were used to collect soil samples after the test. Krohn notes that

> The tanks were [Enrico] Fermi's idea. They were Army tanks without a gun turret, lead-lined, and had a trap door cut into the bottom, and the idea was for the tanks to go up to Ground Zero right after the shot, open the trap door, and reach down and scoop up dirt...and take it back for measurements. [Robert D. Krohn, personal communication 1996]

Tank rights-of-way had to be marked out to keep the tanks, from which visibility was limited, from running over experiments (Robert D. Krohn, personal communication 1996). Range poles and flag poles were used for this purpose.

Comments/Results

As noted above, these samples enabled the test personnel to determine the yield of the blast with close accuracy. This method proved to be the most accurate for determining the yield of a nuclear explosion and became a standard method.

Sources

Bainbridge 1976:Figure A-14; Robert D. Krohn, personal communication 1996; TR-200, 392A, 392B; Figure 1.

Primacord Stations

General

J. E. Mack was in charge of this experiment, the object of which was to measure the velocity of the blast by photographing the detonation of primacord by the arrival of the blast wave. This was done with Fastax cameras, stationed at West 10,000, that made about 10,000 exposures per second.

Figure 35. Tanks in 100-ton crater area after May 7 test (TR-200).

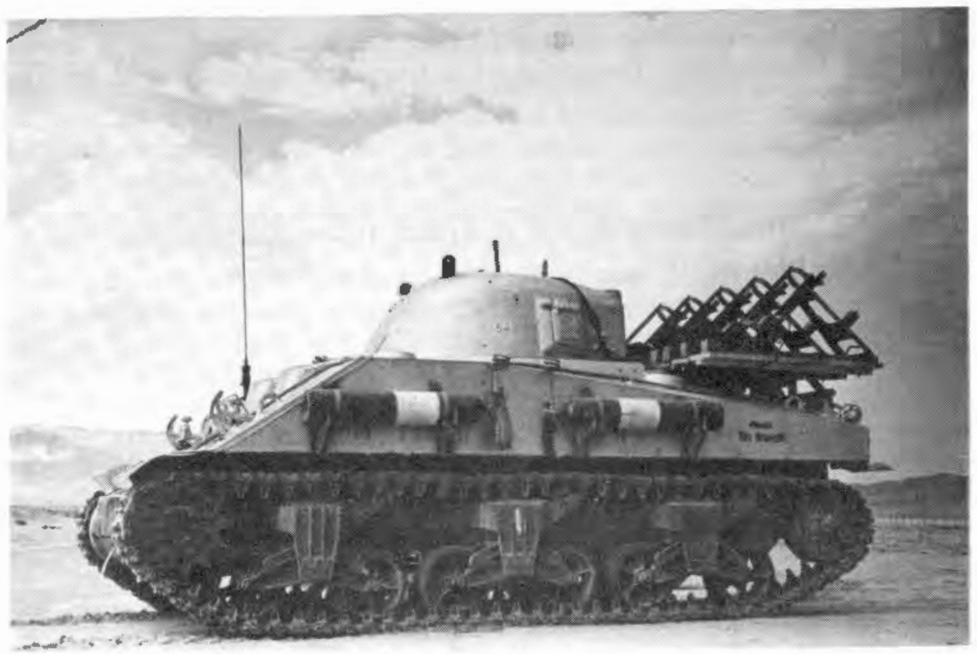

Figure 36. Tank for collecting soil samples (TR-392A).

Location

The detail location plan shows six primacord stations, at 400 west, 500 and 600 south-southwest, and 400 and 600 north-northwest of Ground Zero.

George A. Economou (personal communication 1997) remembers only two stations. The number was probably reduced from that proposed in the plan. He does not remember exactly where the stations were, nor the dimensions of each station.

Configuration

Bainbridge (1976:64) states that Mack was in charge of an experiment that measured mass velocity of the blast with suspended primacord and magnesium flash powder viewed by Fastax cameras. Both the primacord and the powder were commercially available. Berlyn Brixner was Mack's alternate in the group called TR-5 (Bainbridge 1976:23). Robert Krohn [personal communication 1996] explains that

> Primacord was in a sense a fuse. It was an explosive wrapped in an inert cover, like a cable, very much like an electrical cable. We used primacord on the project quite a bit where we wanted to make something happen at very good timing and we wanted to use an explosive to do it....Julian Mack used primacord to set off the magnesium...a signal at zero time [wonld create] a known and proper delay.

A memorandum dated May 18, 1945, from J. E. Mack to John Williams (Record Group A-84-019, Box and Folder 54-15, LANL Archives) states that

> ...the primacord will be mounted in the form of an "L" with its vertex at the station specified and its arms extending radially outwards and vertically upwards. The primacord circuit will be armed electrically and set off by shock switches.

George A. Economou (personal communication 1997) explained that this experiment used shock switches. The switch was essentially a foil with a contact behind it. Because Benjamin C. Benjamin's Torpex charge experiment also used shock switches, Economou and Benjamin helped each other to set up (see Figure 20). The shock switches were supposed to set off a detonator, which would then set off the primacord. The detonator may have been taped or otherwise fastened to the primacord—Economou does not remember exactly.

Economou stated that he prepared the primacord in a stable at Trinity Base Camp that he used as a workshop. He obtained duct tape, laid the primacord on the tape, spread magnesium flash powder around it, and then wrapped and rolled the cord and powder together. He then attached the primacord to a pipe or pole.

The rationale of the primacord is that maximum damage occurs when the direct shock wave and the shock wave reflected from the ground come together.

Figure 37. Helium balloon for raising primacord (TR-165).

Although there are photographs (TR-161, 164, and 165) of Economou raising a helium balloon to hold up the vertical segment of primacord (Figure 37), Economou states that the balloons were not used. The photographs were taken during tests (Economou remembers that he tested the balloon at Los Alamos, but it is clear from the photo that he also did so at Trinity). Winds drove the balloons downward, making them impractical. The actual configuration was somewhat in the form of a fence: vertical sections of primacord 4 or 5 ft high were set up with a horizontal segment suspended along them. It was assumed that when the primacord detonated, it would create columns of glowing magnesium particles, and the shock wave passing through these columns would be photographed.

Economou noted that during a dry run, a primacord was set off by static electricity, scaring everyone in the area.

Comments/Results

When the atomic bomb was detonated, the primacord detonations occurred prematurely. The shock switches were set off by thermal radiation within a few microseconds of the atomic blast, rather than by the shock wave as intended. Benjamin's Torpex charge experiment failed to record any results for the same reason.

Sources

Bainbridge 1976:23, 64; George A. Economou, personal communication 1997; Robert D. Krohn, personal communication 1996; TR-161, 164, 176; and Figure 1.

Metal Stakes (Earth Displacement)

General

Steel stakes 2 ft long and 1 in. in diameter were located at various distances from Ground Zero along two perpendicular lines, in order to measure permanent earth movement near the tower. Bainbridge calls them "steel stakes for level and vertical displacement measurements" (Bainbridge 1976:65).

> Seismographs and other devices measured earth motion during the explosion....A variety of instruments measured the earth motion. At Penney's suggestion, the Corps of Engineers erected stakes at accurately measured distances from Ground Zero. After the 100-ton test...and after Trinity, the positions of the stakes could be measured so as to determine the permanent displacement of the ground near the explosion. The yield could be estimated from these data. [Hoddesen 1993:353]

Location

Reines (1945:Figure 1) shows stakes at 70, 90, 120, 150, 200, 250, 300, 400, and 500 ft in each direction from the tower. However, these are not the alignments shown in Figure 1 in this report. The north-south line of steel stakes is about 15° east of north, with the east-west line perpendicular to the north-south line.

Comments/Results

Measurements after the atomic test using the steel stakes as guides determined the depth and width of the crater. Reines (1945:Figure 3) notes that the stakes were recovered; presumably, then, none of them remains in place.

Sources

Bainbridge 1976:65; Reines 1945.

Neutron Balloon, Winch, and Ground Station

General

Neutron measurements were the responsibility of Group TR-3B of the Y Project. This group included Richards, Krohn, and Klema, who were among those interviewed for the present report.

The neutron balloons were camera stations. The cameras were "cellophane-catchers" (see description below). The ground stations were aluminum boxes (see description below).

See Figures 38 and 39.

Location

Figure 1 shows a neutron ground station and winch at South 660, about 75 yd west of the alignment, and a balloon at South 460. There is another ground station at South 330. Krohn (personal communication 1996) says that there were two balloons, the second being only about 50 to 100 yd to the west of the first. He speculates that one symbol on the detail location plan stands for both balloons. Bainbridge (1976:79) likewise refers to "two barrage balloons."

Richards (1993:79) has it that there was a balloon-born camera and a ground camera at 300 m, and that both were destroyed by the blast.

Configuration

The large barrage balloons are illustrated in TR-393 (Figure 38). They were LA-D8 balloons from the Sharonville Engineer Depot in Sharonville, Ohio (Record Group A-84-019, Box and Folder 55-14, LANL Archives).

Krohn (personal communication 1996) says that the balloons were suspended on fine-strand stainless-steel cable. Piano wire was often used on barrage balloons, Krohn says, but was considered too fragile for this test.

Krohn (personal communication 1996) also states that the ground cameras were anchored with four angle irons, one at each corner, set in concrete.

Bainbridge (1976:53) says that there were three cellophane-catcher cameras, one on a balloon and the other two at ground stations. Richards (1993:74) also refers to three cameras, as does Hoddesen (Hoddesen et al. 1993:375). Krohn (personal communication 1996) remembers that there were four cameras, two on the ground and two aloft. Evidently, there would be no purpose for a second balloon if there were no second balloon-born camera.

Richards (1993:53) says that

> We designed a 'cellophane catcher camera' where a motor pulls a cellophane tape rapidly between two ^{235}U coated plates. Neutrons from the explosion would produce fission in the ^{235}U. Some of the resnlting fission fragments will escape from the ^{235}U surface and be caught on the rapidly moving cellophane tape. The subsequent measurement of the radioactivity of these fission fragments caught on the tape gives the desired time differentiated neutron record.

Figure 38. Barrage balloon for flying neutron camera (TR-393).

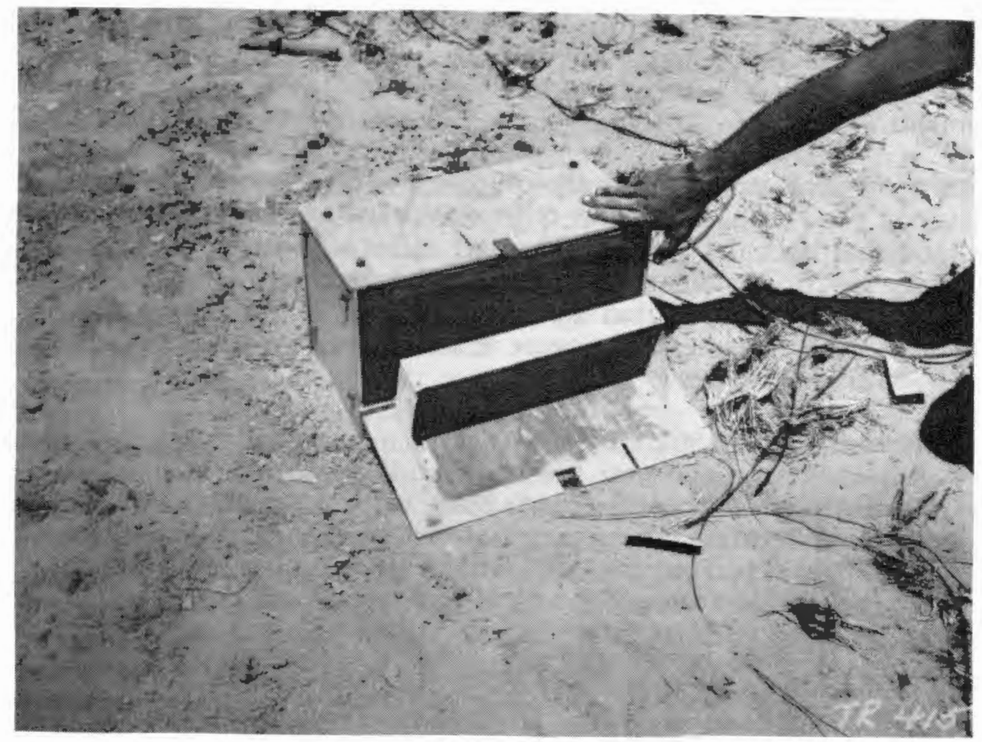

Figure 39. Neutron time camera box, 1995 (TR-415).

Krohn (personal communication 1996) adds that

> The neutrons would cause fission in the 235...the fission fragments, having considerable energy, would leave the plate and some of them would go in the direction of the cellophane passing by and catch in the cellophane. So then afterwards a measurement of the radioactivity from the fission fragments on the cellophane would give you a timed record of the neutron activity....There were four stations for taking neutron measurements—two of them were on barrage balloons and two of them were on the ground...The ground stations were heavy aluminum boxes with about a two inch thick wall, set right on the ground, and within these boxes were the same kind of neutron cameras that [Hugh T.] Richards was flying on the barrage balloons.

The neutron time cameras had trigger signals but ran on batteries (Robert D. Krohn, personal communication 1996).

Krohn (personal communication 1996) added that he flew one of the balloons, while Richards flew the other, meaning that they raised the balloons to position.

See Rieder and Lawson (1995:41) and Figure 39. This is a box for a neutron time camera. Krohn (personal communication 1996) built the boxes.

Richards (1993:74) notes that the cameras were used for the 100-ton test and suffered no damage.

Comments/Results

Krohn (personal communication 1996) notes that one airborne camera survived in good shape, while "the other was pretty badly burned by the ball of fire," and that both the burned and intact cameras yielded records. However, Bainbridge (1976:54) states that only one camera survived long enough to give a record (the ground station further south—at South 600, according to Bainbridge. This disagrees with Figure 1, which has it that the ground station was at South 660).

Hoddesen and others (1993:373) state that

> One of the barrage balloons was tethered near the tower [Ground Zero] on a long metal cable. The thermal radiation [of the blast] vaporized the cable, but its particles were still visible on the film, indicating the path of the shock wave.

Sources

Bainbridge 1976:63, 79; Hoddesen et al. 1993:373; Robert D. Krohn, personal communication 1996; Richards 1993:73 ff, personal communication 1996; TR-393, 415.

Sulphur Threshold Detectors and Gold Foils

General

Ernest D. Klema assumed principal responsibility for neutron measurements with cadmium-covered gold detectors and sulphur detectors.

The eight sulphur threshold detectors were sections of iron and aluminum pipe with caps, into which liquefied sulphur was poured and then permitted to set (Ernest D. Klema, personal communication 1996). The detectors were intended to catch and count neutrons emitted by the blast.

Slow neutrons from the bomb induced short-term radioactivity in the gold foils. These foils, placed around Ground Zero at distances from 300 to 1,000 yd, measured the number of neutrons per square centimeter.

Location

Two witnesses say that the sulphur threshold detectors were on a line from Ground Zero due east, all within perhaps 200 yd of Ground Zero. There were eight of them (Ernest D. Klema, personal communication 1996; Robert D. Krohn, personal communication 1996). The sulphur detectors are not shown on Figure 1.

Bainbridge (1976:55) notes that:

> E. Klema determined the number of neutrons per square centimeter per unit logarithmic energy interval as a function of distance from the bomb by measuring the activation of cadmium-covered gold foils which had been calibrated in a graphite block....Klema also measured the number of fast neutrons from the nuclear explosion at a point 200 m. distant using sulphur as the detector.

Hawkins (1983:243) notes that:

> Delayed neutron measurement was done in three ways—by using a cellophane catcher and ^{235}U plates both on the ground and when airborne; by using gold foil detectors to give an integrated flux, and by using sulfur threshold detectors. For the cellophane catcher method, a record was obtained from the 600-m station. With the gold foil method, the number of neutrons per square centimeter per unit logarithmic energy interval was measured at seven stations ranging from 300 to 1,000 m from the explosion. Of the sulfur threshold detectors, only two of the eight units were recovered, and these gave the neutron flux for energies of 3 MeV at 200 m.

Configuration

Klema (1945) does not specify how the sulphur detectors were set up. A memorandum dated May 18, 1945, to Bainbridge, Williams, and Richards (no sender identified) and titled "Proposed Layout of Equipment for Gadget Shot" (Record Group A-84-019, Box and Folder 54-15, LANL Archives), states that the detectors will simply be "placed on the ground southwest of O and within 100-200 meters of O. Some or all of these cylinders may have light steel cables attached to aid in their recovery."

Some details of the method of preparation of foils are given in Klema (1945):

> Gold foils were placed in protective tubes and scattered around the bomb [Ground Zero]. Slow neutrons from the bomb induced short-term radioactivity in the gold. The gold foils, which were scattered from 300 to 1,000 m around Ground Zero, measured the number of neutrons per square centimeter. Two other experiments measured neutron activity. One gave a time-differentiated neutron record using cellophane films passing rapidly between two ^{235}U plates to catch fission fragments. The other used a sulphur detector with a threshold of 3 MeV to measure high-energy neutrons. [Hoddesen 1993:357]

An undated report in Record Group A-84-019, Box and Folder 54-15, LANL Archives, states that "the foils will be placed inside iron housings and will be mounted on short wooden posts." Klema's phase "scattered around the bomb" then, does not necessarily mean that the foils were simply placed on the ground.

A report by Morris Blair, David Frisch, Ernest Klema, and H. T. Richards dated March 29, 1945 (Record Group A-84-019, Box and Folder 53-18, LANL Archives), further specifies that the gold foils "are to be encased in small aluminum tubes (4 cm. long, with an outside diameter of one inch), which in turn will be placed in cadmium cans. One end of the cadmium can is to be a circular disc soldered in place, and the other is to be a spun lid held in place by scotch tape" (p. 3). These were then to be put in aluminum pipes with aluminum caps screwed on each end.

Comments/Results

Seven of the gold foils were recovered (an early memo suggests that this would be done from one of the lead-lined tanks to be sent into the area after the test) and yielded the total number of neutrons per unit area (Bainbridge 1976:50; Hoddesen et al. 1993:375).

Two of the sulphur detectors were also recovered. These remained in the possession of Ernest D. Klema. In the course of the present investigation, he offered the detectors to the White Sands Missile Range Museum on permanent loan, which was subsequently arranged.

Sources

Bainbridge 1976:54, 63; Ernest D. Klema 1945, personal communication 1996; Richards 1993:73.

Crusher Gauges

General

Crusher gauges were placed near Ground Zero to measure peak pressure (maximum blast pressure).

Location

There was a total of 32 gauges. The gauges were placed on alignments north and south of Ground Zero (Marley and Reines 1945b:4), but these were not necessarily the North and South alignments—the report is not clear on this point. Pairs of ball gauges were placed at 75, 100, 150, 210, and 325 ft from Ground Zero in each direction. One cylinder gauge was placed at 50 ft, one at 75 ft, and pairs at 100 and 150 ft in each direction.

Configuration

The cylinder gauges were copper cylinders 1/2 in. long and 3/8 in. in diameter, fitting loosely into a hollow steel cylinder provided with a piston and obdurating cup. Micrometer calipers were to be used after the test to determine the maximum pressure to which the piston had been subjected, but none of these gauges was recovered. Such gauges were in use by the Army Ordnance Department and the Navy Bureau of Ordnance.

See Figure 40 (from Marley and Reines 1945b).

The copper-ball crusher gauges were small, spherical copper balls enclosed in a steel cylinder with a piston and obdurating cup. These gauges were supplied by Cal Tech.

The gauges were placed in steel gauge containers, hollow steel cylinders screwed to the top of a 1 1/4-in. diameter steel bar 18 in. long. The whole container was driven into the ground before the gauge was inserted so that the top was flush with the surface. After the gauge was inserted, the open end was fitted with a nozzle to govern the rate of application of pressure to the gauge inside.

Comments/Results

Search parties combed the area a month after the shot. They recovered five of the gauges. At the other locations, only the steel bar or anchor stake remained in place.

The crusher gauges that survived gave maximum pressures that were multiplied by reflection from the ground.

The crusher gauges positioned directly under the bomb were destroyed by the blast pressure multiplied by its reflection from the ground. No gauge within 200 ft of Ground Zero survived. The remaining five ball gauges measured pressures ranging from nearly 5 tons per square inch at 208 ft to slightly more than 1 ton per square inch at 327 ft. [Hoddesen 1993:376]

Sources

Bainbridge 1976:64; Marley and Reines 1945b; not shown on Figure 1.

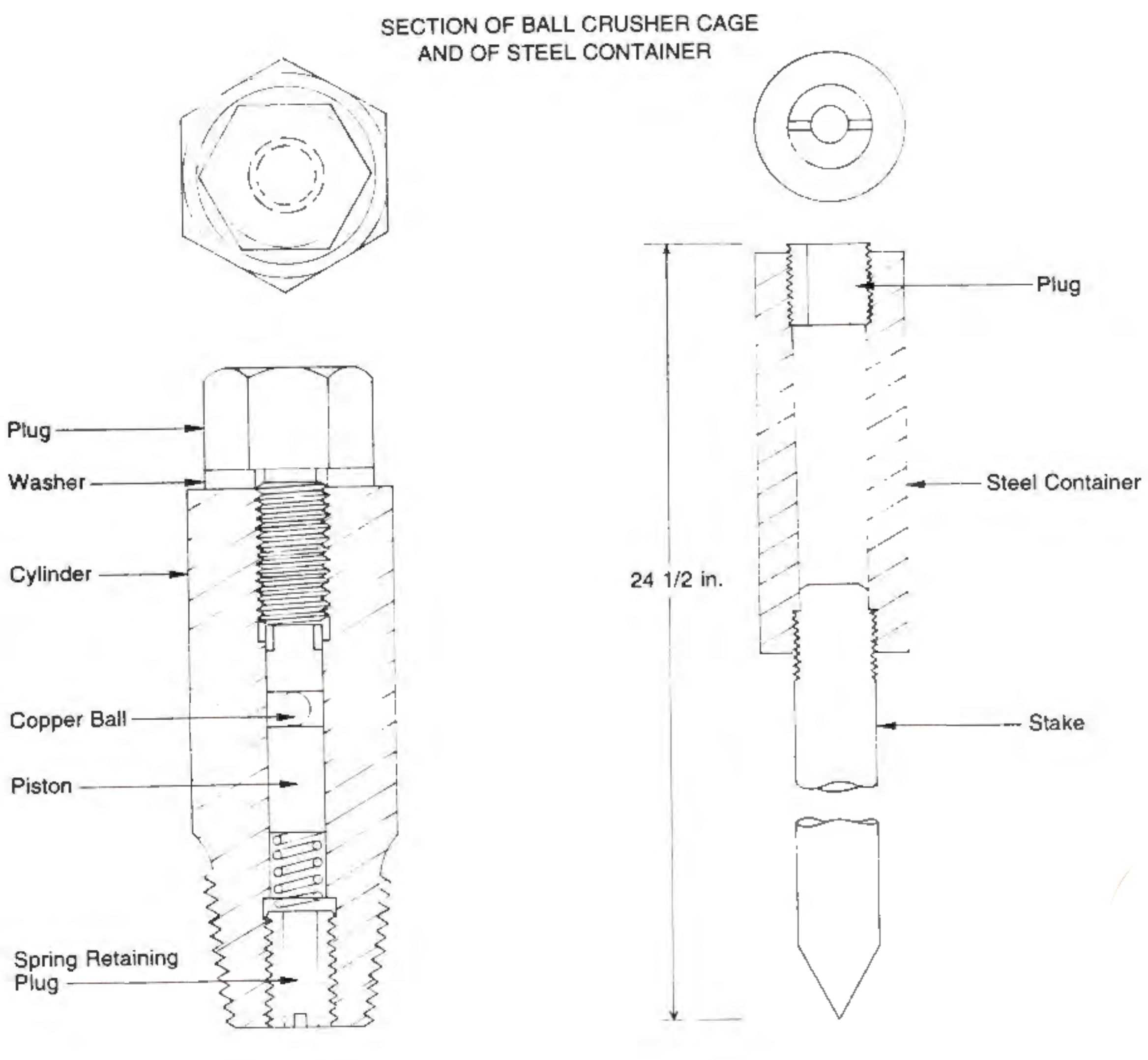

Figure 40. Crusher gauge (from Marley and Reines 1945b).

Roads

General

> The original plan was simply to use dirt roads, but the dust clouds from them rose half a mile in the air, and the scientists detoured across the land whenever possible. 'The soil wasn't very good' [Ted] Brown [the general contractor] recalled in a 1980 interview. 'It was mostly gypsum sand. You can pack it down, let three trucks go over it and the fourth truck turns the road into three in. of flour. It didn't water very well. There was no local source for water so we trucked water in from the Rio Grande. We had twenty trucks coming in twenty-four hours a day'....Fortunately, someone found a mica-gravel deposit in the vicinity of the steel tower, which they dug and spread about six in. deep on the roads. This they watered thoroughly and then primed with a coat of asphalt. Groves eventually ordered twenty-five miles of road treated in such fashion, at a cost of about $5,000 a mile [See Figure 41]. The area immediately under the metal tower was treated in a similar manner. [Szasz 1984:34]

Location

Figure 1 shows roads on the five alignments: North, South, West, Southeast and East. See Figure 41, showing the end of the pavement, and Figure 42. About 22 mi of new roads connected the bunkers, while the test site was bisected by some 25 mi of upgraded roads. In addition, the road from Ground Zero to West 10,000 was extended 28 mi west to the railroad siding at Pope, New Mexico.

Sources

Hoddesen et al. 1993:34; TR-283, 799; Figures 1 and 2.

Communications Lines

Location

Figure 1 shows center lines extending north, south, and west to the observation shelters, as well as east and to true north. The center lines are distinguished from the roads, but appear to be coterminous with the communications lines.

Configuration

"Communications lines....Little low poles were just loaded with lines....the poles were just tall enough you could drive a low vehicle under them....a lot of lines were laid on the ground..." (Krohn, personal communication 1996; see Figures 43 and 44).

Figure 41. Paved road—South alignment (TR-283).

Figure 42. Pope Road, looking toward Ground Zero point (TR-799). This road was built to haul in Jumbo, the device intended to contain a nuclear chain reaction. It was never used, but remains at the site.

Nearly 500 mi of communications and signal cables were strung to link the bunker and instrumentation sites. All signal lines within 3,000 yd of Ground Zero were laid in underground trenches.

The paper entitled "Layout and Wiring at Trinity" (n.d., Record Group A-84-019, Box and Folder 56-4, LANL Archives) tells us that the communications wires were standard Signal Corps W-110-B single twisted pair wire.

Sources

Figures 1 and 2.

Seismographs

General

Krohn (personal communication 1996) says that four or five seismographs were used at Trinity. He describes these as standing about 2 ft high and being 8-10 in. square, looking "very much like a computer tower." He believes WSMR has at least one of these.

Location

There were five three-component portable seismographs, located in San Antonio, Carrizozo, Tularosa, Elephant Butte, and at North 9,000 (Leet 1945). Hoddesen and others (1993:354) also note that there was a seismograph at the base camp.

Comments/Results

> The seismographs...detected a tremor at N 9,000 and at San Antonio 28 miles away. The maximum motion at San Antonio was less than enough to produce a small crack in the wall of a house. Other seismographs at Tucson, El Paso and Denver, alerted by the Manhattan Project to the possibility of a tremor, showed no tremor. The scientists correctly predicted that the damage radius would be on the order of 1,000 yds. [Hoddesen et al. 1993:375]

Sources

Robert D. Krohn, personal communication 1996; Leet 1945; Figure 2.

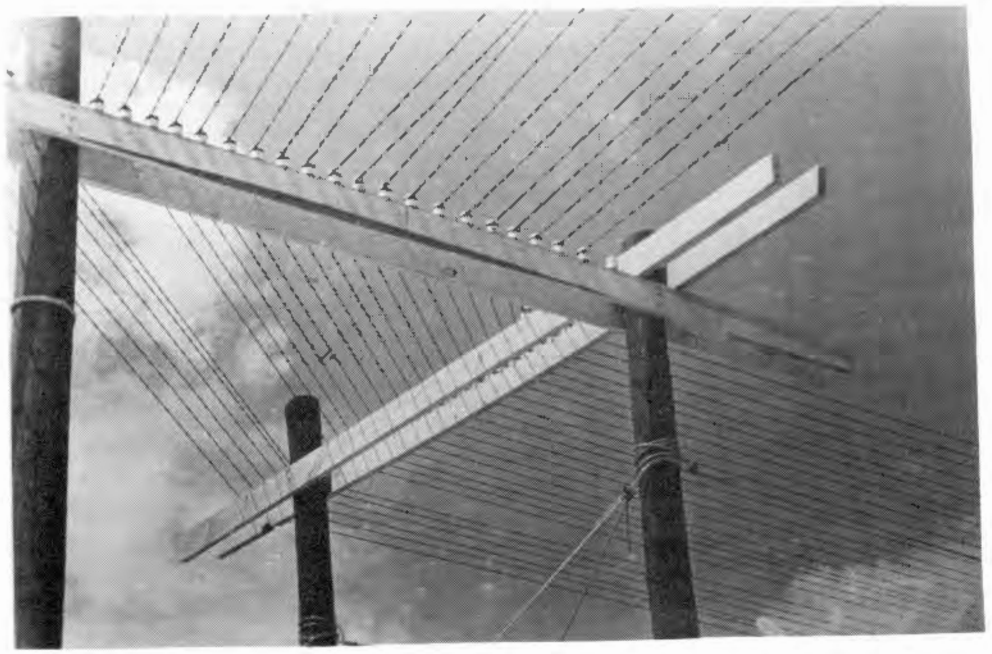

Figure 43. Signal wires near South 10,000 (TR-371).

Figure 44. Communications poles on west alignment, about 700 yd west of Ground Zero, 1997 (photo by Stephen P. Merlan).

RESULTS OF THE TESTS

"The most important result of the Trinity test was that the implosion worked, with sufficient efficiency" (Hoddesen et al. 1993:374).

The yield and size of the fireball were the basis for the determination to set the fuses of the Hiroshima and Nagasaki bombs for 1,750 ft ± 100. The experiments collected a wide array of data (Appendix 3), despite the radiation that spoiled some results and the unexpected levels of radiation that caused others to fail. Two of the flash bombs, or two pairs of them, worked as noted, but were unnecessary.

> Most of the experiments performed as expected. Not all provided useful data, however, since the yield was almost three times larger than predicted. The blast-measuring devices performed quite well, but most of the gamma-ray measuring devices were overloaded by the gamma-ray flux, which was much larger than expected. This occurred because extrapolations from chemical explosives were somewhat inaccurate (because chemical explosives put more of their total energy output into the blast wave, whereas nuclear explosives put less into blast and more into thermal radiation, as well as a minor amount into neutrons, gamma rays, and fission products). Because the laboratory had anticipated the lower proportion of energy in the blast wave, but not the greater yield, the blast-measuring devices could cope with the output of the blast, whereas the gamma-ray measuring devices had too much to measure. Even so, the piezoelectric blast gauges were thrown off scale and no records were obtained. The higher-than-anticipated gamma-radiation also fogged the motion picture films slightly.
>
> The blast damaged Segrè's gamma-ray yield experiments. The airborne meter, unprotected by the ground, was destroyed before it could transmit to the recorders. The ground chamber fared better, but the great amount of radiation overloaded the meters in the first few seconds. Still, from about 10 to 20 sec after the blast, Segrè's team obtained reliable readings. Unfortunately, few neutron detectors survived the blast. Of the three cellophane cameras, only the 600-m station survived long enough to give a 'moving picture' of the neutrons. Only two of the eight sulphur threshold detectors were recovered; they recorded high-energy neutron fluence at 200 m. Seven of the gold foils were recovered and yielded the total number of neutrons per unit area.
>
> The results from Trinity led to some modification of the bomb and to a slightly different design for the core of the Nagasaki bomb. [Hoddesen et al. 1993:377]

Intense gamma rays caused the measurement of detonator simultaneity to fail, but the fact that the bomb exploded showed that the simultaneity was adequate.

Mack and Brixner (Record Group A-84-019, Box and Folder 55-16, LANL Archives, "Photographing the Bomb") note that one Mitchell camera, set for its highest speed, burned up. Several cameras failed to operate and several were incorrectly aligned. Two films were spoiled in processing. Much of the motion picture film of later stages of the explosion was severely underexposed, and some was overexposed. The remaining film contained numerous overlaps and duplications. However, it yielded the data necessary for a determination of the space-time relationships of the test.

Marley and Reines (1945b) discuss the attempt to recover the crusher gauges. Jorgensen (1945b:6) mentions the recovery of the mechanical impulse gauges. Bainbridge (1976:50) notes that some of the gold foils were recovered. A memorandum dated September 11, 1945, from K. T. Bainbridge to the Trinity group leaders (Record Group A-84-019, Box and Folder 55-13, LANL Archives), notes that J. Robert Oppenheimer had given his approval for the withdrawal of equipment from Trinity, and that much of it would go to Sandia Laboratory. It was recommended that the reject W-110-B wire be left on the poles, and segments of it may still be found on the site. Some of the cameras went to Sandia; some were returned to other projects from which they had been borrowed. The memorandum notes that most of the blast and earth shock equipment had already been returned to Los Alamos. Most of the individual reports do not mention the recovery or disposition of the various gauges.

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Appendix 1. Levels of Badges.

An "Instruction Sheet" dated July 4, 1945, stated that the identification badges in use were to be replaced by color-coded badges.

Edwin N. York (personal communication 1997) described a color-coded badge system consistent with that described on the Instruction Sheet, but stated that it was already in effect when he arrived at Trinity in late 1944.

No one else interviewed had a particular recollection of the badges, except to say that everyone had one, and that they were of a single numerical sequence. Several group photos taken at Trinity in the spring of 1945 show a circular badge about $1^1/2$ in. in diameter, worn pinned on the wearer's chest.

The *Instruction Sheet* proposed a system of four colored badges. White badges indicated that the wearer's duties required him to have a general knowledge of the scope and significance of the project. Blue badges were to be worn by those who did not require a general knowledge of the scope and significance of the project; they received only limited classified information. Examples given were technicians and secretaries.

Red badges were to be worn by persons who had no need of technical classified information. Examples given were clerks, warehouse employees, and certain machinists.

Yellow badges were to be issued to persons not employed by the principal contractor, but whose duties required them to be present on the site.

The only specific reference to location was a mention of Los Alamos Canyon. Trinity was not named in this paper.

Appendix 2. Interviews.

Persons interviewed face to face:

Jack W. Aeby
Española, New Mexico

Benjamin C. Benjamin
Albuquerque, New Mexico

William E. and Margaret Caldes
Tijeras, New Mexico

Felix DePaula
Fairview, New Mexico

Benjamin C. Diven
Los Alamos, New Mexico

J. C. Hoogterp
Los Alamos, New Mexico

Robert L. Walker
Tesuque, New Mexico

Joseph L. McKibben
White Rock, New Mexico

Berlyn Brixner
Los Alamos, New Mexico

Robert D. Krohn
Los Lunas, New Mexico

Richard J. Watts
Los Alamos, New Mexico

Henry H. Barschall
Department of Physics
University of Wisconsin
Madison, Wisconsin

Persons interviewed by phone and letter:

Marvin R. Davis, Sr.
Bartonville, Illinois

George A. Economou
Pittsburgh, Pennsylvania

Theodore Jorgensen, Jr.
Lincoln, Nebraska

Charles T. Menz
Baldwin, New York

Robert R. Wilson
Ithaca, New York

Ernest D. Klema
Northeast Harbor, Maine

also

Engineering Department
Tufts University
Medford, Massachusetts

Hugh T. Richards
Department of Physics
University of Wisconsin
Madison, Wisconsin

Edwin N. York
Kent, Washington

Others:

Darol Froman of Santa Fe is referenced in Bainbridge 1976:63 and is also pictured in *Los Alamos 1943-1945: The Beginning of an Era* (pg. 43). He declined to be interviewed for this project.

Appendix 3. Trinity Experiments Summary Table.

Instrument	Sources/Personnel	Location	Configuration	Purpose/Results
Tower (bomb site)	Bainbridge 1976; B.C. Diven, p.c. 1996; Hoddesen et al. 1993; Reines 1945.	Ground Zero	Bottom half of Blaw-Knox tower. On concrete footings 102 ft high. Bolted steel sections in 25-ft levels. Base about 25 ft square; top platform about 15 ft square.	Designed as site of bomb and its explosive assembly. Bomb detonated successfully on July 16, 1945.
Single and double ionization chambers and coaxial cables	Bainbridge 1976; B.C. Diven, p.c. 1996; Hoddesen et al. 1993; Reines 1945; R.R. Wilson, p.c. 1996. The single-chamber experiment was designed by Bruno Rossi and the dual-chamber experiment by Robert R. Wilson.	Ground Zero extending north	Ionization chamber connected to distant oscilloscope by copper tube 3 in. in diameter with internal cylinders of copper of decreasing radius.	Measures increases in gamma radiation. Rossi's experiment produced a substantially accurate result; Wilson's experiment produced a less accurate result. Rossi's simpler method made it the method of choice in future tests.
Piezoelectric gauges	Bainbridge 1976; R.L. Walker 1945, p.c. 1996.	Sources disagree. Walker states that there were six gauges on the north alignment and six on the south. Figure 1 indicates gauges only on the south alignment, at 600, 610, 780, 790, 800, 970, 980, 1,200, and 1,210 yd from Ground Zero.	Quartz crystals stacked in a pile and connected in parallel by copper electrodes. The gauges were mounted 6 ft above the ground on the horizontal arm of an inverted L-shaped pipe; the arm extending toward Ground Zero. Connected to amplifiers by coaxial cable.	Designed to determine air blast. No result during Trinity test. The traces were thrown off scale by radiation.

Appendix 3. Trinity Experiments Summary Table (cont.)

Instrument	Sources/Personnel	Location	Configuration	Purpose/Results
Piezoelectric gauge amplifiers	Bainbridge 1976; R.L. Walker 1945, p.c. 1996.	Sources disagree. Figure 1 indicates amplifiers only on south alignment, at 930, 940, 1,110, 1,120, 1,130, 1,300, 1,310, 1,530, and 1,540 south of Zero. However, if Walker is correct, there may have been amplifiers at same locations north.	Electrical calibration system and arming relay in an amplifier box. Shock-mounted in a metal cabinet on sponge-rubber supports and housed in a sponge-rubber lined plywood box hung on screen door springs from a pipe A-frame. Battery power supply in separate unit, connected to amplifier by a short cable.	The piezoelectric gauges failed to yield any records.
Gamma sentinels (Type A)	Bainbridge 1976; Moon 1945; R.R. Wilson, p.c. 1996.	South 400, 800, 1,500; West 800, 1,500; North 400, 800, 1,500; East 1,500.	Lead box with window past which film is moved by a spring- or battery-operated motor.	Results unknown.
Gamma sentinels (Type B)	Bainbridge 1976; Moon 1945.	Bainbridge and Moon agree that there were 16 sentinels. Moon specifies five at North and South 400, 800, 1,500, 4,000, and 10,000 yds; one at East 1,500; and five at West 800, 1,500, 4,000, 7,000, and 10,000. Merlan and Kirkpatrick also located a sentinel box at West 1,000.	Ionization chamber in series with source of voltage and argon discharge tube. Battery-driven. At stations closer to Ground Zero than 4,000 yd, the unit rested on a shelf inside a small shelter or box buried in a hill of sand. The unit was under a steel lid that worked on a pivot and rose by the action of a counterweight. Those further out than 4,000 yd were in plain wooden boxes. Each station was connected by phone lines to one of the three main shelters (North, South and West 10,000).	Designed to gauge energy released from the atomic reaction. The 400- and 800-yd stations were damaged by the explosion. The others survived, showing a strong wave of ionization traveling north. North 400, South 400, 800, and 1,500, and West 800 were made inoperable by the explosion; the others still worked.

Appendix 3. Trinity Experiments Summary Table (cont.)

Instrument	Sources/Personnel	Location	Configuration	Purpose/Results
Excelsior-filled boxes	Marley and Reines 1945a.	West alignment at 275, 400, 800, 1,600, and 3,200 ft from Ground Zero.	Boxes 1 ft square by 6 in. deep, filled with excelsior and covered with mesh-wire netting, backed by a mound of dirt and secured to heavy wooden stakes.	Designed to test incendiary effects of the bomb. At 275 and 400 ft the boxes were completely destroyed. At 800 ft the box was scorched. At 1,600 ft it was destroyed and scattered. At 3,200 ft it was scorched, but whole.
Geophones	Bainbridge 1976; Coon and Houghton 1945a.	Twelve geophones at 800, 1,500, and 9,000 yd North and South, in pairs.	Low-frequency balance-beam geophones. (Four were Geophysical Research Corporation Type SG-3.) Type 810 cathode-follower amplifiers, an alternating-current operating control box, and a balancing panel. Records were taken on Heiland A-401R 6-trace oscillographs. Geophones planted in pits 36 by 12 by 24-in. filled in with loose dirt.	Designed to measure earth shock. Six of the 12 geophones gave readable records, but several of those closest to Ground Zero were knocked out by the electro-magnetism that accompanied the explosion.
Geophone amplifiers	Bainbridge 1976; Coon and Houghton 1945a.	Each at a distance of 740 ft from the geophone pair.	Amplifiers and power supplies mounted in pairs in wooden boxes, which were suspended by springs from a beam across the top of the amplifier chamber. Amplifier cases were metal boxes inside the wooden boxes, which were lined with sponge rubber and felt. Chambers were closed with a cover of plywood and felt, which had dirt piled on it. Twisted pairs were laid on the ground from the pits to the pole line and were carried on knob insulators on the cross arms of the poles, or laid in shallow trenches (within 3,000 yd of Ground Zero).	See above. This test confirmed that wider damage would result from exploding the bomb in the air than on the ground.

Appendix 3. Trinity Experiments Summary Table (cont.)

Instrument	Sources/Personnel	Location	Configuration	Purpose/Results
Paper box gauges	Bainbridge 1976; Graves and Hoogterp 1945; Hawkins 1983; J.C. Hoogterp 1945, p.c. 1996.	Fifty-two gauges set up on the North, South, West, and Southeast alignments.	Aluminum foils covering holes of different diameters were mounted over the front of a wooden box of 1/2-in. plywood with airtight joints. The partitions were 1/4-in. plywood. Two pieces of 1/4-in. masonite were drilled with various hole sizes, with a 1/32-in. neoprene gasket cemented to the outer plate. Each foil was clamped in place with machine screws and wing nuts. Wood screws held the plate to the box. The boxes were mounted on 4-by-4-in. or 2-by-4-in. posts 5 or 6 ft high.	Designed to determine air blast. The box gauges gave results, but their measurement of the yield was low by about a factor of two.
Flash bombs	Bainbridge 1976; E.N. York, p.c. 1997.	Sources disagree. Bainbridge says that there were 47 flash bombs. York says only 12 were actually built; these were set up in pairs in a single area 6 mi northeast of Ground Zero.	York states that 12 flash bombs were mounted on six pairs of posts joined by crosspieces. TR-296 and 329 appear to show single flash bombs. The flash bombs were obtained from the Army Air Corps. Flashers were designed by a civilian technician and set on the ground between the posts. The flash bomb was taped above the flasher on a horizontal crosspiece about 4 ft high, or to the vertical post.	The flash bombs were set up to illuminate the cloud (it was not known whether the cloud would be self-luminous). Although they were timed to detonate at two-minute intervals, only two pairs actually detonated. This experiment was unnecessary because the cloud remained luminous.
Torpex charges	B.C. Benjamin, p.c. 1997.	A single line of tripods; the closest about 100 yd south of Ground Zero; others at diminishing intervals on the South alignment. "Fewer than 20."	3/4-in. pipe tripods with a Torpex charge taped to the top of the tripod. Shock switches were designed to activate the Torpex charges. Each assembly had a battery on the ground, with a circuit connecting it to a detonator.	J.E. Mack proposed to photograph the charges (from West 10,000 with Fastax cameras) as the shock wave set them off, and thus measure mass velocity and shock-wave expansion. Intense thermal radiation set off the switches prematurely. This experiment yielded no result.

Appendix 3. Trinity Experiments Summary Table (cont.)

Instrument	Sources/Personnel	Location	Configuration	Purpose/Results
Ground and balloon-borne ionization chambers	J.W. Aeby, p.c. 1997; Bainbridge 1976; Fermi 1995.	Ground station (bunker) at Northwest 600. Balloon station at Northwest 450. May also have been station at Northwest 4,000.	Each station consisted of two ionization chambers, with two resistors feeding two amplifiers, actuating four Heiland galvanometers recording on paper (however, Aeby says that the recorder at Northwest 600 was an Esterlein-Angus galvanometer). Pairs of ionization chambers were enclosed in steel drums. The airborne pair was flown on two balloons in tandem.	Emilio Segrè and others attempted to measure the time dependence of the gamma radiation. The ionization chambers at Northwest 600 obtained significant readings. The airborne detectors were destroyed. No readings from them are known to exist.
EDG	Figure 1.	Two units at 100 yds North and South; two units at 200 yd North and South.	Unknown.	Unknown. "EDG" may mean "earth displacement gauge," or some other type of gauge.
Slit cameras	Memorandum of 4-13-45 from J.E. Mack to K.T. Bainbridge; Figure 1.	Two at 275 yd north and west of Zero, 75 ft from alignment in both cases.	X-shaped aperture in plate of tuballoy between two plates of tuballoy; mechanism for moving a film across the plane of aperture.	Unknown. Probably produced only heavy radiation fogging.
Pinhole cameras	Bainbridge 1976; Halpern and Moon 1945; Memorandum of 4-14-95 from O.R. Frisch to K.T. Bainbridge.	Two, at 150 yd and 275 yd south of Ground Zero.	Camera about 2.5 ft long and 1 ft in diameter at rear, tapering to about 6 in. at front. Pinhole was a tapered channel of lead, .3 mm in diameter at narrowest point.	Pinhole cameras were intended to capture gamma rays and take a picture with them. Two buried motion picture cameras at 275 yd south of Ground Zero would then take optical pictures of the screens. Radiation greater than 100 times predicted caused heavy fogging; no result.

Appendix 3. Trinity Experiments Summary Table (cont.)

Instrument	Sources/Personnel	Location	Configuration	Purpose/Results
Impulse meters	Bainbridge 1976; T. Jorgensen, Jr. 1945a, 1945b, 1966, p.c. 1996; Figure 1.	Sources disagree. Bainbridge states that only one gauge was installed. Jorgensen (1945b) states that there was one meter at 350, one at 520, and two each at 600, 720, 1,100, 2,000, and 4,000 yds West of Zero. Figures 1 and 2 show meters at 350, 520, 600, 720, 1,100, 2,000, and 4,000 West.	Squirt-gun type gauge. Cylinder filled with water, with a piston at one end and a plate with holes at the other. A rod from the piston through the plate carries a stylus, which marks a rotating smoked-glass disc. Cylinder is mounted on the side of an air-tight dural box. Motor carrying the glass disc is mounted in the box. Disc is rotated by a motor powered by a six-volt storage battery. Motors were modified windshield-wiper motors. Dural boxes containing the piston, cylinder, glass disc, motor and relays, batteries, and message register mounted in a 3/4-in. plywood box supported by screen-door springs on a 1¼-in. iron-pipe frame.	Designed to measure peak pressure of air blast. Eight gauges recovered almost undamaged. Three recovered in damaged condition. One closest to blast not recovered. Only four gauges gave any result, and these only functioned in a small range of impulses. Closest result was equivalent of 10,000 tons of TNT—low by a factor of two.
Condenser gauges	Bainbridge 1976; Bright 1945; R.D. Krohn, p.c. 1996; Figure 1.	Sources disagree. Bainbridge says that only one gauge was installed. Bright says that eight gauges were put in positions west of Ground Zero. Figure 1 shows locations at 800, 1,000, 1,190, and 1,400 West of Ground Zero.	Microphone manufactured at Cal Tech. Aluminum plate and backing plate, with cable taking capacity to an oscillator. Transmitter units mounted on 15-ft poles.	Intended to measure shock-wave pressure. Only one record was obtained. Bright states that the value for peak pressure was accurate to within about 10 percent.

Appendix 3. Trinity Experiments Summary Table (cont.)

Instrument	Sources/Personnel	Location	Configuration	Purpose/Results
Peak pressure gauges	Littler 1945.	Twenty gauges. Twelve at 900, 1,100, 1,300, 1,500, and 1,700 ft West. Eight at 800 (2), 1,000 (3), 1,000 (3), 1,500 (2) and 2,000 (1) yd West.	Twelve gauges consisted of six spring-loaded pistons to cover a range of pressures. Gauges set in 4-by-2-by-3-ft trenches and bolted to lengths of channel iron set in concrete in center of trench. Eight gauges obtained from Road Research Laboratory, England. Movement of piston detected by permanent displacement of friction-held rod. Gauges strapped to tops of 4-by-4-in. wooden posts, insulated against vibration by sponge-rubber pads between the gauges and posts.	Designed to measure peak pressure of air blast. Gauges at the top of the trenches at 900 and 1,300 ft, and at 800 yd were blown off their supports by the blast. The others gave readings, but these were useless because the gauges were set far below the actual pressure.
Excess velocity gauges	Bainbridge 1976; H.H. Barschall 1945a, 1945b, p.c. 1996; Hawkins 1983; Hoddesen et al. 1993.	Ten receivers, at 400, 500, 700, 1,000, and 1,400 yd northwest and southeast of Ground Zero.	Five-pound charge of pentolite suspended at height of 15 ft at East 50 yd fired 3 sec before nuclear explosion. Gauge was a permanent-magnet speaker mounted in a plywood box padded with felt, open on side facing Zero, suspended about 6 ft above ground by 8 springs fastened to iron-pipe frames. Audio transformer mounted in the box. Transmission line was cable with 5 twisted pairs of copper wire leading from the gauge to 10,000-yd shelters (North and South).	Designed to measure blast velocity. Among the most successful of the experiments, the excess velocity gauges gave substantially accurate measurements.
Tanks	Bainbridge 1976; R.D. Krohn, p.c. 1996.	Not fixed. Two tanks entered the crater after the test.	Army tanks without gun turret, lead-lined, and with trap doors cut in the floor.	Intended to measure energy released from the atomic reaction. Analysis of contaminated soil gave substantially accurate reading of yield. This method proved to be the most accurate for determining efficiency of a nuclear explosion, and became standard.

Appendix 3. Trinity Experiments Summary Table (cont.)

Instrument	Sources/Personnel	Location	Configuration	Purpose/Results
Primacord stations	Bainbridge 1976; G.A. Economou, p.c. 1997; R.D. Krohn, p.c. 1996; Figure 1.	Sources disagree. Figure 1 shows six stations. Economou states that only two were actually built; no information as to locations.	Plans called for stations in "L" configuration. Economou states the stations were actually configured like sections of fence, with a horizontal primacord set up on verticals, each 4 or 5 ft high. Shock switches of same type used in Torpex charge experiment were intended to set off a detonator that would ignite the primacord. Detonator may have been taped or otherwise fastened to the primacord. Economou rolled and wrapped magnesium powder around the primacord lengths with duct tape. Fastax cameras at West 10,000 were set up to record the displacement of the columns of magnesium particles.	Intended to measure shock-wave expansion. Primacord was set off by the intense radiation rather than by the blast pressure as intended. No result.
Metal stakes	Bainbridge 1976; Reines 1945.	Sources disagree. Reines gives 70, 90, 120, 150, 200, 250, 300, 400, and 500 ft north, south, east, and west. Figure 1 shows alignments about 15° east of north, with other alignments at right angles to this.	Steel stakes 2 ft long by 1 in. in diameter, driven vertically into the ground with only top 1/2 in. protruding.	Designed to gauge permanent horizontal and vertical earth displacement. Measurements after the test determined the depth and width of the crater.

Appendix 3. Trinity Experiments Summary Table (cont.)

Instrument	Sources/Personnel	Location	Configuration	Purpose/Results
Neutron balloon, winch, and ground stations	Bainbridge 1976; Hoddesen et al. 1993; R.D. Krohn, p.c. 1996; H.T. Richards 1993, p.c. 1996.	Sources disagree. Most indicate two ground stations and two balloons. Figure 1 shows neutron ground station and (balloon) winch at South 660, about 75 yd west of alignment, balloon at South 460, and ground station at South 330. Krohn says there were 2 balloons. Bainbridge refers to 2 balloons, but also says there were 3 cameras, one airborne and 2 at ground stations. Richards and Hoddesen both refer to 3 cameras.	Barrage balloons suspended on stainless-steel cable. Ground cameras anchored with four angle irons, one at each corner, set in concrete. Cellophane catcher camera consisted of a motor pulling a cellophane tape between ^{235}U-coated plates.	Designed to measure delayed neutrons. In this experiment, fission fragments escaping from the blast would be caught on the moving cellophane tape. Subsequent measurement would give a time-differentiated neutron record. Bainbridge states that only one station (on the ground at 600) survived long enough to yield a result.
Sulphur threshold detectors	Bainbridge 1976; E.D. Klema 1945, p.c. 1996; Richards 1993.	Eight detectors on a line east from Ground Zero, all within about 200 yd of Ground Zero.	Liquefied sulphur poured into short sections of capped iron or aluminum pipe. Method of setting up not specified; probably on pipe or stake. Memorandum of 5-18-45 suggests attaching a light steel cable to aid recovery.	Designed to gauge energy released from the atomic reaction by measuring delayed neutrons. Two detectors were recovered and indicated neutron flux for energies of 3 MeV at 200 yd.

Appendix 3. Trinity Experiments Summary Table (cont.)

Instrument	Sources/Personnel	Location	Configuration	Purpose/Results
Gold foils	Bainbridge 1976; Klema 1945; Richards 1993.	Scattered around the bomb from 300 to 1,000 yd around Ground Zero.	Gold foils in protective tubes. The tubes were cadmium cans 4 cm long, with an outside diameter of 1 in. One end of the can was probably soldered in place, while the other was a spun lid held in place by scotch tape, then placed in an aluminum can with screw-on caps at either end. The cans may have been set up on pipes or stakes.	Designed to gauge energy released from the atomic reaction by measuring delayed neutrons. Seven of the gold foils were recovered and yielded total number of neutrons per unit area.
Crusher gauges	Bainbridge 1976; Marley and Reines 1945b.	Thirty-two gauges on alignments north and south of Zero. Pairs of ball gauges at 75, 100, 150, 210, and 325 ft from Zero in each direction. One cylinder gauge at 50 ft, one at 75, and pairs at 100 and 150 ft in each direction. These directions are not necessarily the major alignments North and South; this is not clear.	Cylinder gauges were copper cylinders 1/2 in. long by 3/8 in. in diameter, fitting loosely into a hollow steel cylinder fit-ted with a piston and obdurating cup. In use by Army Ordnance Department and Navy Bureau of Ordnance. Copper-ball crusher gauges were small, spherical copper balls enclosed in a cylinder with a piston and obdurating cup. Supplied by Cal Tech. The steel cylinder containers were screwed to the top of a 1 1/4-in.-diameter steel bar 18 in. long. The container was driven into ground before the gauge was inserted so the top was flush with the surface. After the gauge was inserted, the open end was fitted with a nozzle to govern the rate of application of pressure to the gauge.	Designed to measure air blast. Five of the gauges were recovered one month after the test. At the other locations only the steel bar or anchor stake remained in place. Gauges gave maximum pressures (up to five tons per square inch at 208 ft). However, these readings are far below actual pressures.

Appendix 3. Trinity Experiments Summary Table (cont.)

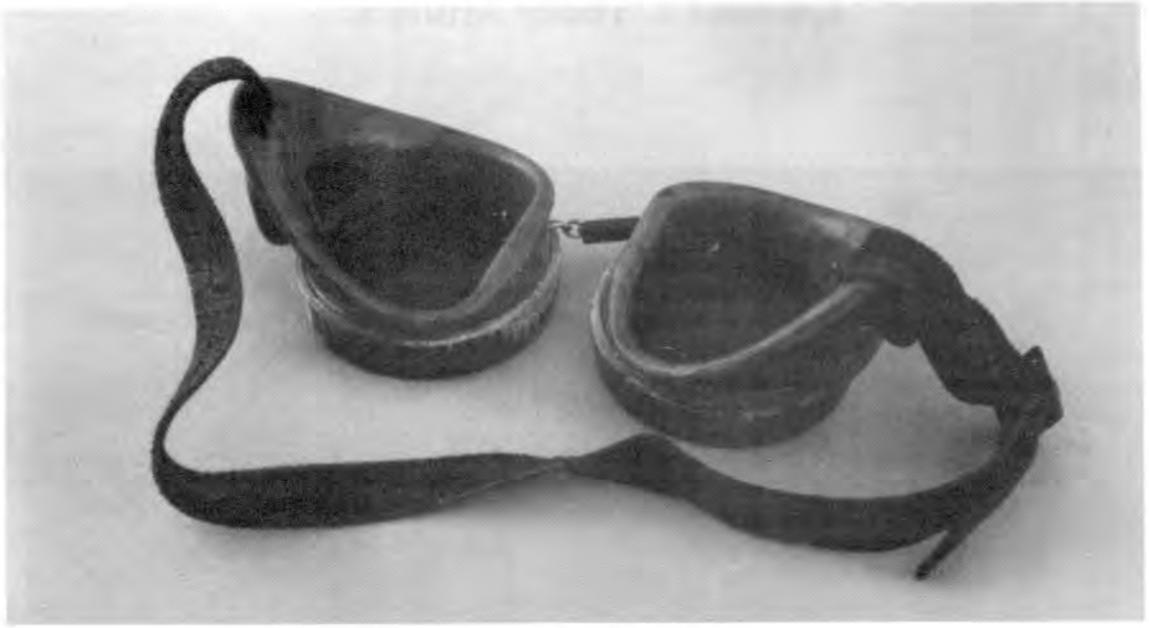
Instrument	Sources/Personnel	Location	Configuration	Purpose/Results
Communications lines	Figures 1 and 2.	North, South, East, West, and true north from Ground Zero to 10,000-yd stations.	Unmilled trunks 7 or 8 ft high, with milled crosspieces, carrying standard Signal Corps W-110-B single twisted pair wires.	Designed to carry signals. Communications poles and wires carried most signals effectively, although they were not efficient enough to ensure simultaneity of stereopair cameras at Campana Hill.
Seismographs	R.D. Krohn, p.c. 1996; Leet 1945; Figure 2.	Five three-component portable seismographs at San Antonio, Carrizozo, Tularosa, Elephant Butte, and North 9,000. One seismograph at Trinity Base Camp.	Leet three-component portable seismographs.	Designed to measure earth shock. Seismographs at North 9,000 and San Antonio obtained records.

Appendix 4. Trinity Artifacts.

Linda Hart and David Kirkpatrick
Photographs by Jo Ruprecht, Las Cruces

Willson Safety Goggles

According to the manufacturer's box, these are Willson Goggles Type RW50 with Shade-6, Willson-Weld lenses. Frames are marbled-brown, Bakelite plastic. The right eye cup is labeled "MADE IN U.S.A." in raised letters just above the triangular ventilator insert. Circular, black plastic (probably Bakelite), indirect ventilator is labeled "WILLSON" in raised letters. "9MM" is hand etched into black plastic, shade-6 (see photograph of outside of box) lens at the 9 o'clock position. The lens is protected to the front by a clear cover lens and both are held in place by a black plastic ring that screws onto the eyecup like a flashlight lens assembly. Visible lens diameter is $1\,^{13}/_{16}$ inches. The diameter of the front of the ring is $2\,^{1}/_{16}$ inches; the diameter of the back of the ring is $2\,^{3}/_{16}$ inches. An elastic headband, measuring $^{1}/_{2}$ inch wide and slightly less than $^{1}/_{16}$ inch thick, is attached to the goggles through a $^{7}/_{16}$-inch-long and $^{1}/_{16}$-inch-wide slot. A $^{5}/_{8}$- by $^{11}/_{16}$-inch, black metal guide with four slots allows adjustment of strap length. The left eye cup is a mirror image of the right, except that "PATENTED" appears in raised letters above the ventilator insert instead of "MADE IN U.S.A." The two eye cups are held together by an adjustable chain bridge (7 metal links running through a hard, black plastic tube [$^{15}/_{32}$ inch long by $^{3}/_{16}$ inch in diameter]). Bridge has been shortened by one link (see adjustment instructions in photograph of inside of box lid).

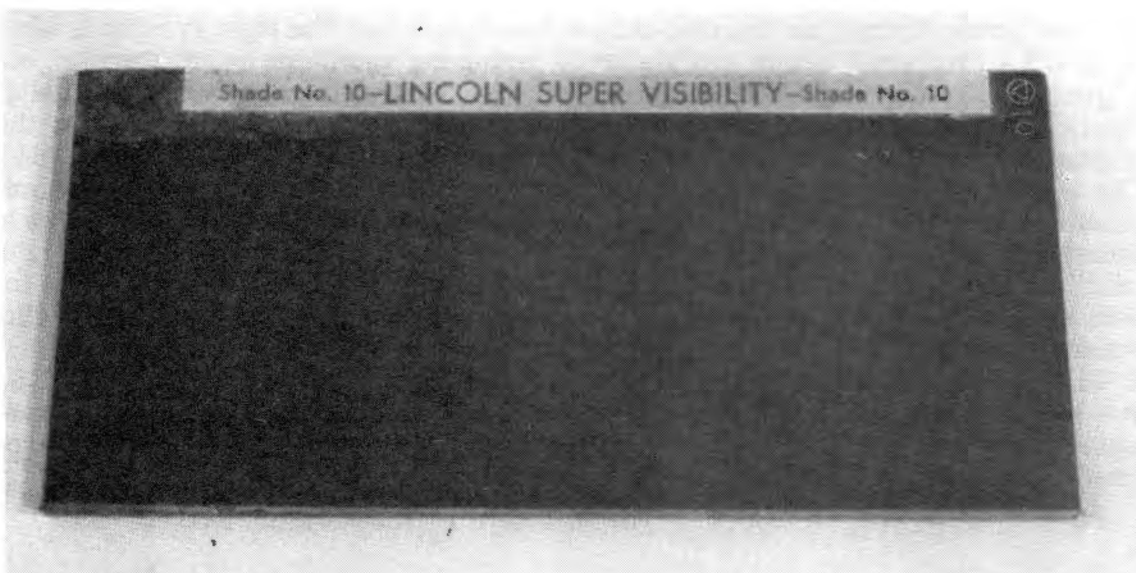


Packing Slip

Light-weight, baby-blue paper measuring $1\frac{13}{16}$ inches long by $\frac{11}{16}$ inch wide (see group-shot photograph). Labeled: PACKED
by No. 15

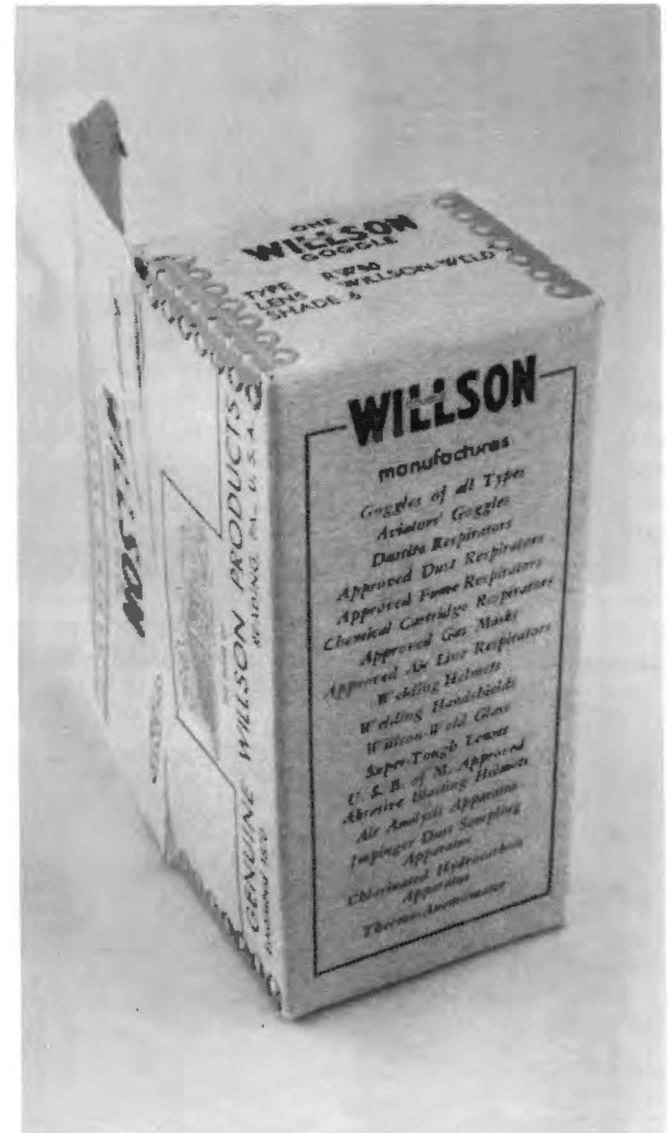
Black Glass Plate

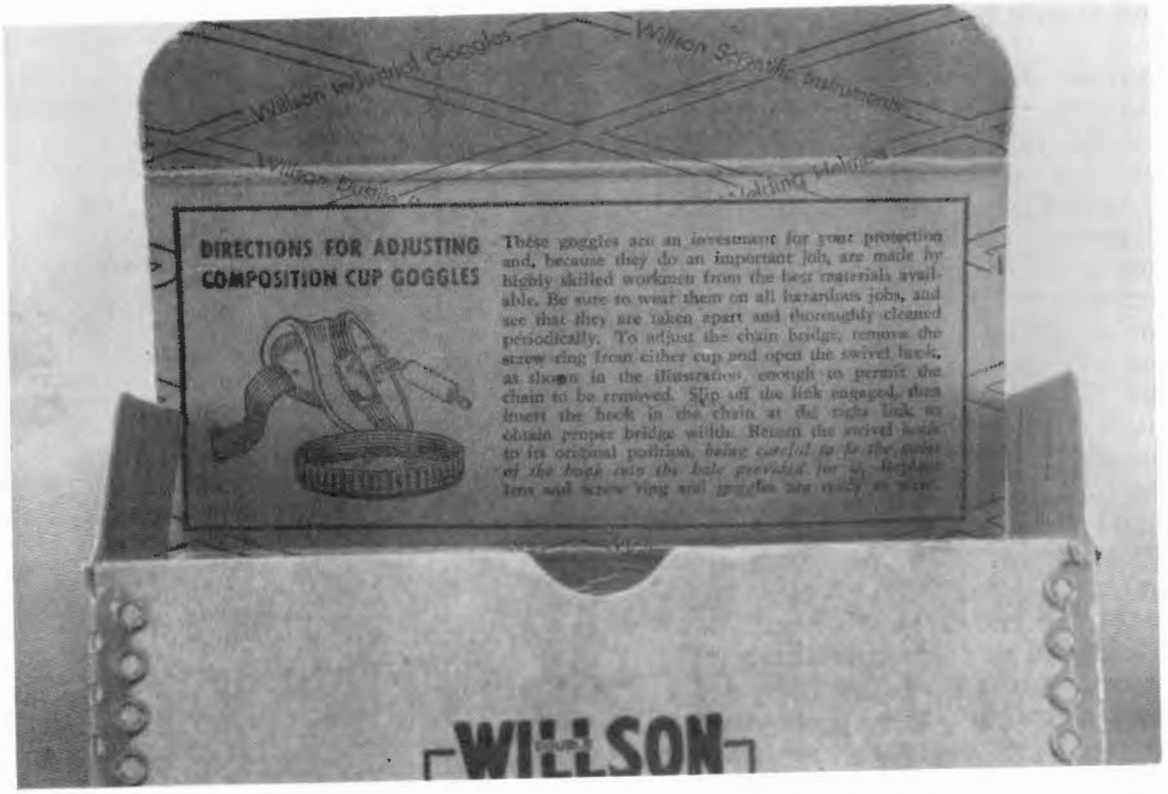
Yellow band labeled "Shade No. 10—LINCOLN SUPER VISIBILITY—Shade No. 10" appears across the top of the 2-inch-high, $4\frac{1}{16}$-inch-wide, $\frac{1}{16}$-inch-thick glass plate. Upper right corner is engraved: ⊘10

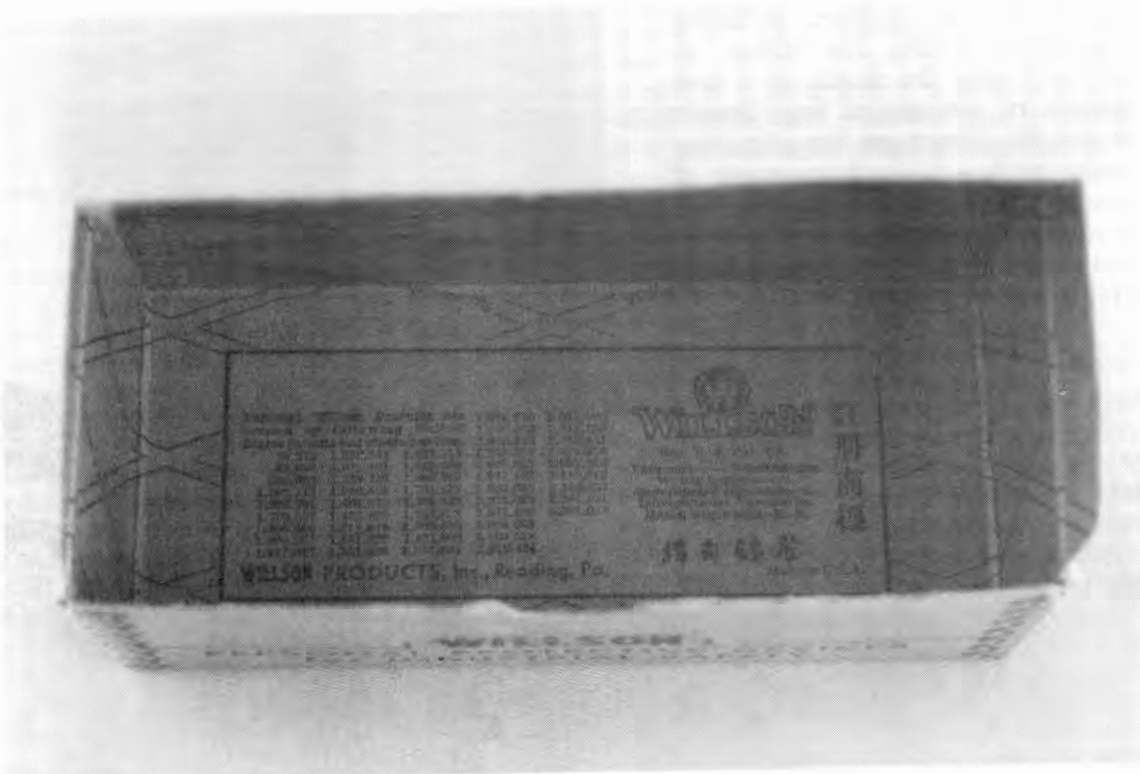


Willson Goggle Box

This green, cardboard, manufacturer's box is the carton for the goggles described above. It measures $5\frac{1}{2}$ inches long, $2\frac{1}{2}$ inches wide, and $2\frac{3}{16}$ inches high. It is held together with green, metal tabs (see box photographs). The outer surface of the lid identifies Willson as a manufacturer of industrial safety products (see photograph of outside of box). Outside on the bottom is a list of the safety products manufactured by Willson (see photograph of outside of box). Outside on the back is an etching of what is assumed to be the Willson manufacturing plant in Reading, Pennsylvania (see photograph of outside of box). Outside on the front Willson is identified as the manufacturer of "personal protective devices for industrial safety" (see group-shot photograph). One end of the outside of the box simply identifies the contents as being a Willson product (see group-shot photograph), while the other end is specific to the goggles, defining them as Type RW50, the lenses as Willson-Weld, and the shade as 6 (see photograph of outside of box). Inside the lid are the directions for adjusting the chain bridge (see photograph of inside of lid). Inside the bottom of the box is a panel listing all the patent numbers held by Willson and identifying the Willson trademark in a variety of languages (see photograph of inside of box). The remaining surfaces inside the box are decorated with a double-line cross-hatch design, where the names of various Willson products are printed along the lines (see photographs showing inside of box). The goggles, the glass plate, and the packing slip were stored in this box.







Aluminum Sulphur Threshold Detector

This device consists of a long nipple (a pipe threaded at both ends with an unthreaded segment at the center) with a cap at each end. The nipple is 3 1/2 to 3 3/4 inches long and 1 1/2 inches in diameter. Each cap measures 1 1/4 inches high. The top section of each is 2 1/8 inches in diameter and 11/16 inch high; the bottom section is 2 3/8 inches in diameter and 9/16 inch high. A "5" is stamped into the top of each cap and into opposite sides of the unthreaded segment of the nipple. This and the detector described below may comprise the fifth of the eight detector sets placed near Ground Zero to catch and count neutrons emitted by the blast. The detector appears to have been held in a vice and had one cap removed using a hammer and chisel, resulting in mutilation of the threads, numerous deep cuts on one cap, and deeply impressed cross-hatch marks from the vise on the other cap. When presented to the WSMR Museum, the detector was wrapped in scraps from white cotton coveralls.

Iron Sulphur Threshold Detector

This detector is basically the same as that described above, except that it is made of iron and the caps are a slightly different shape. It, too, is stamped "5" on the caps and the nipple. Chisel marks are present on both caps. An impressed "C" on the side of each cap probably identifies them as being Crane-brand products. Thread compound is still present in portions of the grooves on the nipple. The detector was never opened, and a solid mass (probably sulphur) remains inside. Assembled device measures 4 inches long and the nipple is 15/16 inch in diameter. Each cap is 1 1/4 inches high. The bottom section of each is 3/8 inch high and 2 1/16 inches in diameter; the top section is 7/8 inch high and 2 1/16 inches in diameter. When presented to the WSMR Museum, this detector was wrapped in what appears to be half a flour sack.

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