Instruments of Operation CROSSROADS

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THOUSANDS of pieces of scientific and technical equipment made Operation CROSSROADS—the atomic bomb tests at Bikini—the most highly instrumented experiment in history. Each of the nearly 100 target ships was in itself an elaborate instrument of test. This is likewise true of the 4,000 animals which "manned" the target vessels during the explosions. The greatest battery of cameras ever assembled (450 exclusive of press cameras) made certain a complete photographic record of the two historic events. An estimated 50,000 still photographs and 265 miles of movie film were taken. And, reinforcing this vast array were hundreds of aircraft and vessels carrying more than 40,000 personnel.

This discussion of the technical aspects of the two atomic bomb tests at Bikini is admittedly sketchy for several reasons. As is well known, many of the resultant data from these tests have yet to be assembled, analyzed, and interpreted, a job which will require years. Also, security regulations prevent a complete description of the tests. And, above all, the entire operation was so enormous and complex that it is far beyond the capabilities of a single mind, much less a single article, to present more than a generalized description of a few aspects of Operation CROSSROADS.

Wherever possible the search for fundamental scientific information was included in the operation. The program stressed the study of the various biological effects of different types of blast injuries, designated in terms of air blast, water blast, solid blast, and radiation blast.

HEAT AND BLAST DETERMINATIONS

The measurement of temperature and pressure within the core of an exploding atomic bomb presents a very great problem. Even under water, an atomic explosion has been said to raise the water to a "comparatively low" temperature of about 1,000,000 degrees. In the atmosphere the temperature is variously estimated to be between 4,000,000 and 100,000,000 degrees.

At Bikini, instrumentation from the simplest to the most complex was relied upon for the determination of the heat and blast forces. In certain instances an idea of the maximal temperature attained could be estimated from a study of the condition of substances that fuse within given ranges of temperature. This, however, is not a very certain criterion. After the air burst it appeared as though a giant blowtorch had momentarily passed over the ships.

In this matter, an important time element is involved. For example, glass particles examined on the *U.S.S. Nevada*, the target ship which had been only a few hundred yards from the explosion, did not exhibit the amorphous appearance expected; instead, fragments of unfused glass were scattered about the deck. This does not strictly mean, however, that the maximal temperature produced by the atomic explosion at the distance of the *Nevada's* position did not exceed the melting point of common glass, but rather that the few moments during which the glass had been exposed to the heat seems to have precluded fusion—an effect comparable to passing an easily combustible article quickly through the flame of a blast burner. On the other hand, secondary fires started in flammable materials by electric short-circuits or by the heat wave from the atomic bomb, did produce temperatures sufficient to fuse glass, as well as certain metals.

The more complicated temperature-measuring devices used at Bikini included recording thermometers and pyrometers. The simplest heat measuring tool was temperature-indicating paint. Parallel daubs of paint which showed color changes for different temperature ranges, were lightly placed on flat metal surfaces on the various target vessels, especially on test sheets of armor plate.

The pressure exerted by the blast wave was determined in a variety of ways. Delicate tourmaline pressure gages were mounted aboard a number of the ships. Simple baroscopes were also used to check values relatively high in the pressure spectrum. Of simple construction, these devices have a small cylinder of compressible metal like copper alloy held against a rigid yoke by a movable piston. The impingement of the blast wave against the piston is to cause deformation of the small metal cylinder, the amount of deformation being an indication of the force involved. These metal cylinders were of known compressive strength.

A simple contact-type gage was employed to measure the blast wave velocity. (Figure 1.) These devices were mounted on the end of a pole, several feet above the deck. The contact device consisted of a small copper vane, separated from a movable wire by a plastic block. Ready for use, the vane and wire were pulled out, away from the block, so as to be nearly touching one another. Upon arrival of the shock wave the vane would be forced against the wire, closing the circuit, and recording by an electric chronometer the instant the circuit closed. Thus, by knowing the actual detonation time for the atomic explosion, the velocity of the initial shock wave could be reckoned with little difficulty.

Another pressure measuring device operated from the compression of a metal bellows, the recordings being produced by a pen writing on a rotating paper drum.

Among the simplest devices used to determine the direction of the blast wave was an ordinary plate-glass mirror. (Figure 2.) Constructed with two folding leaves, the mirrors 7 or 8 feet high, were in four sections secured by wires to the decks of the various target vessels. The mirrors gave a good indication of the direction and force of the blast. After the Able-Day explosion a number of unbroken mirrors were found intact. In general they were the ones which had their edges facing the direction of the origin of the blast wave. The mirror surfaces at right angle to the axis of the blast wave exhibited the most breakage. In many cases the upper section of a mirror would be shattered, the lower unbroken. In others,

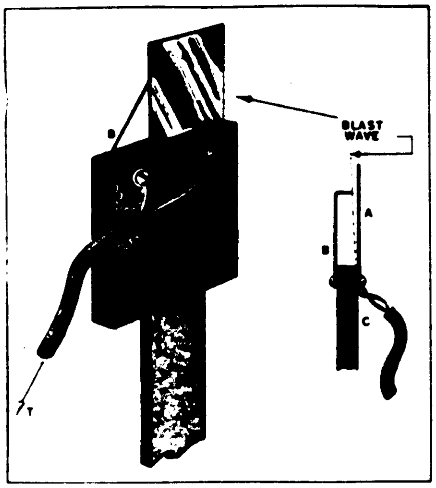


Figure 1

Figure 2

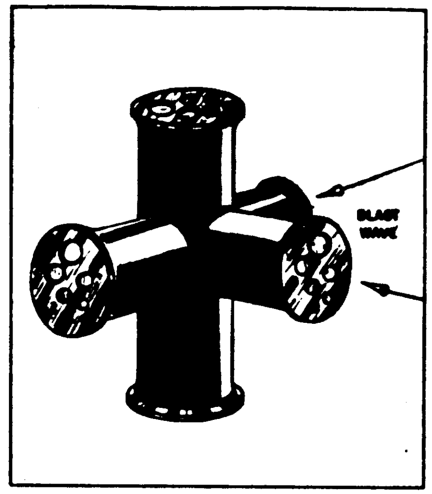


Figure 3

both sections on a leaf would be broken, but the other two sections on the adjoining leaf would not.

Five-gallon tin cans, containing water, were also relied upon as a measure of the relative forces in the blast wave at various distances from epicenter. Each can had a small plastic sheet over its opening, held lightly in place with a strip of scotch tape. The relative deformation of the can, and the amount of water lost, gave an indication of the force of the wave striking it.

Blast force and direction were determined by aluminum foil or "skin" blast gages (Figure 3) mounted on pipe tripods some 10 to 15 feet above deck. These gages had five faces with about a half dozen apertures of varying sizes, each covered with a window of aluminum foil. The largest hole in the instrument was 8 to 10 centimeters in diameter, with gradations down to about 1 to 2 centimeters diameter.

SEA DISTURBANCE MEASUREMENT

The actual and potential disturbances caused in the sea and earth by atomic explosions above or under water had been a matter of concern to many persons since the first announcement of Operation Crossroads. A great deal of speculation caused apprehension among the crews of the ships engaged in the tests. While preliminary studies of wave measurement were made on a small scale at the Hydraulics Laboratory at the University of California at Berkeley and other institutions, certain unknowns made it wise to investigate this phase of the experiment thoroughly. Nevertheless, it is a credit to the Berkeley Hydraulics Laboratory to have predicted, within less than 10 per cent error, the wave heights expected from the air burst.

Scale tests were also made for the underwater burst with small TNT bombs at Solomons, Maryland. Here it was discovered that only a slight depression was made in the surface but that a thin column of water was forced several hundred feet into the air as a result of the initial subsurface test explosion. Because of this fact, the original estimate as to a cavity 150 feet deep, some 500 to 600 feet across, and a water spout some 4 or 5 miles high, had to be revised. There was no way of being completely certain that the energy released by the atomic bomb would act in a way comparable to a TNT charge, however. As it turned out, in the underwater test, the spout shot more than 5,000 feet into the air, having a diameter variously estimated at up to half a mile, containing roughly 10,000,000 tons of froth and water.

The oceanographic section of the technical staff of Joint Task Force One began with a wave measurement unit, added oceanographic surveys, and later added radiological safety reconnaissance. The wave motion unit consisted of thirty-three oceanographic engineers and other specialists. These technicians were provided with a special laboratory ship upon their arrival at Bikini.

The wave measurement staff alone took more than 100 instruments of a dozen different types, weighing nearly 40 tons, to Bikini. Much of this equipment was of new design, constructed especially for the tests. The instruments were installed upon airplanes, islands, ships, and the sea bottom to determine the height, speed, and length of the waves created by the blasts. Undoubtedly, they found good use in the underwater test, when waves a hundred feet high were produced near epicenter.

Instruments for the measurement of wave motion fell into three general categories: Supersonic echo sounding devices and aerial and surface photography. In addition, there were maximum water height recorders on Bikini Island, as well as water-level meters on several of the other islands of the atoll.

The supersonic echo sounders, or fathometers, on sixteen ships scattered throughout the target array recorded the larger waves by the rise and fall of ships, while all eleven supersonic echo sounders mounted on buoys at various sites in the lagoon recorded the passage of smaller waves. A clock started three hours before H-hour on Able-Day actuated the recorders in the echo sounder circuit half an hour before H-hour.

Wave height versus time was recorded by mechanical pressure recorders called "turtles," laid 500 yards apart on the bottom of the lagoon on one or two lines radially away from epicenter. These instruments were capable of recording wave height in the range of about 4 to 200 feet. Some were manually started, others actuated by the blast itself.

Two radio-repeating wave buoys planted 2 and 4 miles from the point of the air burst were capable of transmitting by radio impulses wave heights to one of the PBM photographic planes.

Ten simple maximum water height indicators were mounted near the water's edge at Bikini Island. These devices consisted of a pipe, a contactor strip, a dry cell, and a set of fuses, a number of which burn out as water passes up the pipe. An alternative and simpler type of indicator, using water sensitive colored paper, was also used in the Able-Day test. Several recording tide gages were mounted on piles off one of the remote islands of the atoll, to record the maximum water height at that point.

The wave motion unit, as well as other technical groups in Joint Task Force One, relied heavily upon objective photographic records for analyzable data. The wave motion unit used simultaneous air-ground photographs, stereo-pairs of ground photographs (both camera and television), and right-angle pairs of ground photographs.

Photographs made serially from just prior to the explosions and continuing until several minutes thereafter, provided data for measurements of the height, length, velocity, position, and character of the waves at precisely known times. The analysis of these photographs depends upon chronometering for its success, effected by radio-controlling links which consisted of transmitters in one of the aircraft sending to the ground installations. As each control pulse was received, each camera made one exposure and cycle forward-reading for the next pulse.

Complete photographic coverage of the wave measurement phase of the operation was insured by the use of aerial cameras installed on towers and in airplanes. These were operated by remote radio control, and photographed the waves continuously until they had died out. Some of the cameras were equipped with photoelectric tripping mechanisms which were actuated by light from the explosion.

Seismographs installed on the islands of Bikini Atoll provided a check on the under-earth effect of the bomb, detecting submarine landslides that may have been caused by the explosion. There is little doubt that the majority of the world's seismographers gave careful attention to the records of their instruments for the mornings corresponding to July 1 and 26, Bikini time.

Among the instrument installations used for wave measurements were two television cameras and transmitters located on 75-foot towers 2,000 feet apart, on islands of Bikini Atoll. Television receivers were installed on planes, with motion picture cameras to photograph the screen images. Other television receivers were mounted aboard several ships, enabling close-in visual observation of the scene at a safe distance.

The seismology group of the oceanographic section was concerned not only with the measurement of the amplitude and character of the earth's vibrations resulting from the bomb explosion, but also with subsurface structure of the atoll by means of reflection and refraction measurements similar to those used in geophysical prospecting.

Five seismographs were installed on five of the smaller islands of the atoll with pick-ups on solid coral or rock near the beach.

The general objective of the physical oceanographic survey unit was to establish the current regime and related oceanographic conditions in the atoll and surrounding waters which would influence the scattering and diffusion of radioactive substances from an atomic bomb explosion. Field measurements included surveys with counters, current poles, drift bottles, and fluorescein dye markers in the lagoon. These investigations covered the lagoon entrances and profiles, and the net water exchange between the lagoon and open sea. In general, it was found that the water in Bikini lagoon undergoes a complete change about every 48 days.

Other activities of the physical oceanography group included the collection of water samples at surface and subsurface levels, measurement of temperatures, and determination of the chemical nature of the water. Observations of waves, wind, tides, and weather supplementary to data from other sources were made, as necessary to complete the picture of the prevailing conditions. The oceanographic survey work was carried on by means of current meters, similar to anemometers, by means of current poles, weighted at the bottom and equipped with yellow penants, radar targets and lights, dye bombs which diffused fluorescein or its sodium salt, uranine, at a constant rate throughout the water, and various instruments to measure oxygen, salinity, temperature, diffusivity, and other variables.

In the lagoon it was found that the current flows from north of east to south of west at a velocity of 0.3 knots to 0.6 knots per hour, down-welling the western reef and returning with the counter current at a depth of 40 fathoms. The current poles indicated the complexity of the water movement in the lagoon, as did floreecein sea marker photographed from PBM's flying above.

The fluorescein sea marker is very convenient and economical to use in studies of this kind. The fluorescence of the fluorescein can easily be seen when diluted out to one part in tens of millions of parts of water. With more accurate techniques, one part of fluorescein can be detected in hundreds of millions of parts of water. A sea marker can be seen from the air in bright sunlight at a distance of upwards of 12 miles, and it is also visible on a clear moonlight night.

After the underwater atomic bomb explosion there was considerable speculation among the scientists aboard the *U.S.S. Panamint* as to the cause of bright yellowish, greenish, and blue-white glowing areas and streaks on the sea. Some considered this due to shoaling, others believed that neutronoluminescence or some other form of luminescence occurred in water. In the main, however, the yellowish and greenish streaks and patches were produced by the dye bombs and sea markers which had been employed by the physical oceanography section.

MATERIEL AND EQUIPMENT TESTS

An important phase in the atomic experiment was the exposure of various objects, not strictly scientific equipment in every case, to the force of the explosions.

Large test boards, containing mounted specimens of a variety of articles, as well as narrow shelves for small objects, were mounted on the outer cabin walls of many of the target ships. These test boards were about 4 by 5 feet. Samples of animal fur, leather, fabric, plastic, rubber, asbestos sheet, various paints including metallic paint, aluminum foil and other metals in the form of foil, sheet, and rod were mounted on these boards.

On the narrow shelves at the bottom of these boards a series of pyrometric cones were placed. The usual cones are made from clays of different softening temperatures, and are narrow and about 3 inches high. When a cone is subjected to a temperature equal to or greater than its "falling point," it will soften and the apex will bend over and down. Some of the cones merely ash when a certain temperature is exceeded, and these appeared to be the variety employed on the CROSSROADS test boards. The smallest cone of the series aboard one ship near the *U.S.S. Nevada* was completely ashed, while others in the series were intact.

Plaques of various plastics about a foot square were placed flat on the decks of different target ships. Aboard the *U.S.S. Pensacola*, sheets of Doran were not destroyed, though scorched areas were evident. Many of the test items were merely stacked on top of one another in cardboard or wood boxes, some placed on the open deck, others within the somewhat protected regions of a light antiaircraft or machine-gun well.

Piles of foodstuffs were placed on the decks of the target ships. Canned meats, fruits, and vegetables were laid out on the deck of the *U.S.S. Nevada*, and on ships lying close by. On the *U.S.S. Pensacola*, Vienna sausages had been thoroughly cooked, and their casings charred, presumably by secondary fires. Scorched bits of canned peaches were strewn over the deck of this ship after the first atomic burst. On several ships secondary fires damaged or destroyed many of the stores. Cans apparently ruptured with semi-explosive violence, for their contents were scattered widely over the decks.

Within the holds of the *Prinz Eugen* and the APA 66 none of these effects was produced in secured compartments.

Various pharmaceuticals and medicaments were also placed on the decks of the target ships, in an exposed place to receive the full effects of the blast. Vials of sodium penicillin on the *U.S.S. Navada* were unbroken after the first explosion, and their appearance had not been altered. Bottles of orthotoluidine were broken, and in some cases the pills of this material were fused. On the same vessel most of the bottled and packaged pharmaceuticals, like atabrine tablets, bandages, surgical tape, cotton, tincture of iodine and other common medicaments, were outwardly intact.

A cursory inspection of many of these items, however, does not mean that they remained unchanged. It is likely that physiological and biochemical assays will reveal changes in composition and potency.

PHOTOGRAPHY

The explosion of an atomic bomb has been a rare event in history. We hope it will continue to be so. The four hundred and fifty cameras assembled by the Army Air Forces and the Navy insured a complete photographic record of the two explosions. These cameras were of a wide variety. Both color and black-and-white stills and movies were taken from every conceivable position. Ninety-nine per cent of the photographs came out satisfactorily.

It was not overly difficult to acquire the photographic equipment, but camera placement did pose problems not often experienced in this field. Camera positions had to be protected from the force of the explosion, as well as the intense heat waves accompanying it. Shielding precautions had to be taken against both the mighty gush of penetrating radiations at the instant of the burst and the radioactivity lingering afterwards.

In general, the cameras were placed in three locations:

Close-up photographs were obtained from instruments mounted in six 75-foot steel towers installed on the three islands of Bikini Atoll. These housings were constructed so that after the exposures had been made a sliding lead door, some 6 inches thick, would close over the lenses. Each tower carried a battery of motion picture and aerial cameras encased in an airtight, watertight hood. The half-ton sliding door closed automatically after the exposures had been made, sealing the housing so that the equipment was fully protected against possible subsequent action of radioactive materials.

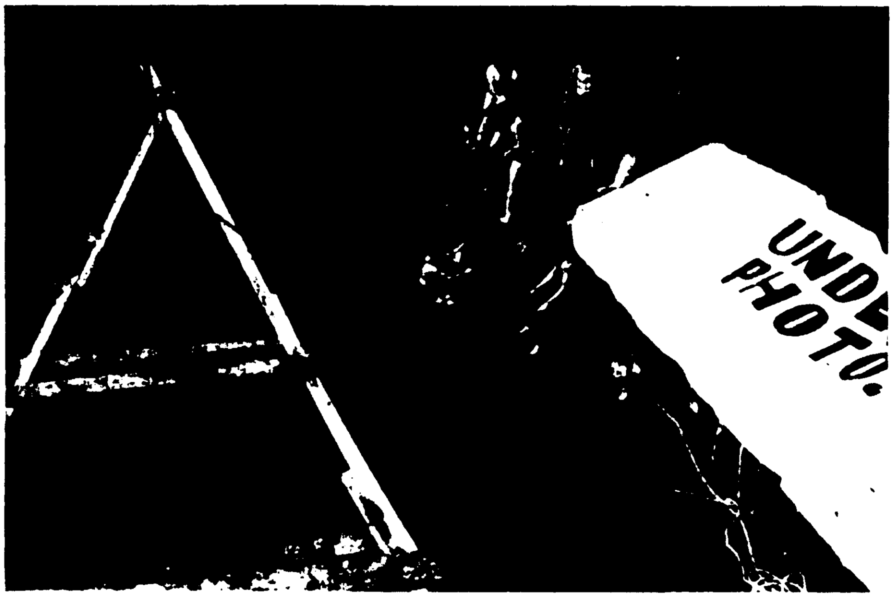
Target ships and observer ships also carried an array of photo equipment. Fourteen of the target vessels had batteries installed on them. On each ship there were three 16-mm gun cameras loaded with Kodachrome magazines. Three cameras were radio controlled and hooked in tandem. Four target ships also had one Sonne and one Jerome camera each. Supplementing the target ships were ten destroyers spaced on a circle at a minimum safe distance from epicenter. Each destroyer carried one 20-inch F56 camera. Two of these ships also had aboard one 40-inch F56 camera, while on one there were added two G651 cameras, one spectograph, and one K-22 40-inch camera. The lenses were set on the center of the explosion and the subsequent actions of the mushroom cloud.

A complete camera umbrella was provided in both tests. The planes carrying the bulk of this photographic equipment consisted of fourteen Army Air Forces craft and seventeen Naval aircraft. Specific planes assigned were eight AAF F-13's, which were actually B-29's converted into photo planes, two C-54's, four B-17's and the four F6F-5P's, four TBM's and four F6F's. The B-17's and the four F6F's, were the Army Air Force and Navy drone aircraft, called "Babes," directed from "Mothers" by radio. The planes carrying the heaviest part of the aerial assignment were F-13's and the C-54's, with each of the former having twenty-eight cameras aboard, and each of the latter carrying twenty-three.

A large number and wide variety of assorted and sundry photographic equipment was employed in Operation CROSSROADS. In addition, wrapped sheets of X-ray film were taped to various parts of the target ships so that their densities after the explosion could be determined, thus giving some idea of the amount of penetrating radiation produced in the initial gush of energy from the explosion.

The specialty photographic equipment included cinema cameras that could run intermittently for 80 hours. Other superspeed cameras operated at 1,000 frames per second. Some were set to record the most brilliant flash of light, others to pick up the faintest gleam. Photographic and similar recording equipment enabled the detection of some 50 octaves of the electromagnetic spectrum, from the hardest X-rays, through the short and long ultraviolet, visible, into the far infrared. In addition, the function of cameras was to photograph the action of the ships at the time of the explosion, the intensity of the light, the growth of the burst, the water waves formed, and numerous other features incident to an atomic explosion.

The actual list is very impressive. Cameras included were: highspeed Mitchell, motion picture; hand-held Eyemo, motion picture; 16-mm. gun cameras, used by aircraft in combat to record kills; AAF K-17, K-18, K-19 and K-20, aerial; Navy F56, aerial; Fastax, motion picture; various sized Speed Graphics; the GR651 camera; Sonne and Jerome cameras, and Ultra-speed Eastman Kodak motion picture. All in-



Underwater Photographic Unit Navy

The photographer is descending from the diving boat. Boom at left holds camera and other equipment underwater.

struments were provided with an assortment of lenses and filters.

While not exactly in the photographic category, the infrared telescope, commonly known as the "icaroscope" was also employed by various observers. These instruments are based upon the brightness-accelerating characteristics of infrared rays acting upon a phosphorescing screen. The writer studied the atomic explosion clouds formed after the underwater or Baker-Day explosion with an icaroscope, and was unable to notice anything unusual. The atomic clouds after the second test were, as a matter of fact, practically invisible through the icaroscope.

Highlighting photographic equipment, however, was the world's largest aerial camera. Five feet long, this immense apparatus was mounted in a B-29, which scientists from the *U.S.S. Panamint* inspected on Kwajalein before the first test. Equipped with a 48-inch telephoto lens it is capable of recording on film the dial of a wrist watch a quarter of a mile away. The camera is a modified AAF-K-18, constructed at the Army Air Forces Materiel Command at Wright Field, Dayton, Ohio.

BIOLOGY AND MEDICINE

One of the functions of Operation CROSSROADS was to extend present knowledge concerning the effects of an atomic explosion on living organisms. Information of inestimable value will eventually be obtained from the medical and biological data obtained through the use of animals. In a living system conditions are vastly more complex than even the most complicated mechanical apparatus could duplicate. It was for this reason that the use of living animals could not have been avoided if reliable information applicable to the protection of humans was to be expected.

Goats, rats, and pigs comprised the majority of the 4,000 animals transported to Bikini Atoll. The fauna and flora normally resident in the area were also subjects of interest, and these organisms will eventually contribute to the fund of knowledge which will save men's lives in the future. From the present knowledge of the atomic bomb it is impossible to take physical measurements and from them predict with any accuracy just what would have been the effect upon humans. This holds true whether an injury does or does not result in death. Such information can only be obtained from living organisms. The decision to use animals was made only after all available means for mechanically measuring the anticipated physical and biological effects had been investigated and proven inadequate.

Radiological hazards are sinister. A person is never aware of the dangers until the insidious effects of excessive irradiation or of poisoning by radioactive

Figure 4. Test Animals Anointed with Protective Ointment Navy

substances appear as manifest catabolic changes. One can do nothing but rely upon palliative methods of therapy and wait for the end. The use of animals was wholly justified at Bikini, for atomic bombs are not the only weapons which nuclear physics has made practical in recent years. The menace of other forms of radioactive warfare is not to be discounted in view of the more spectacular atomic bomb. Consider that only a pound of radioactive poison with an activity equivalent to that of radium is potentially capable of wiping out our population three times over again.

Most of the experimental animals were transported to Bikini aboard the *U.S.S. Burleson*, whose holds had been converted into pens for the 200 pigs, 200 goats, and 3,000 white rats. Some 40 men with farming experience were chosen to attend the animals.

The animals were used to every advantage. Some of the goats were tethered in exposed positions on the decks of the target ships; others were let free to roam in the compartments, and a few were placed within gun turrets. The pigs were freed in the compartments, but the rats were kept in cages placed at various sites aboard ship. The National Cancer Institute collaborated in the study, providing 120 white mice of cancer-susceptible strain. Later, the animals that survived are to be compared with both normal and unexposed mice from the same strain as to their sensitivity to carcinogenic agents.

Of the animals not deliberately selected for experiment, mention should be made of the German brown rats which infested the *Prinz Eugen*. These animals inhabited the vessel when she was taken over by American seamen. After the Able-Day explosion the captain of the *Prinz Eugen* reported that no dead rats were seen, and apparently all of them had survived the initial stages of the blast.

Hematologic studies were paramount before and after both explosions. Blood pictures give the best indication as to radiation illnesses and recovery. Radiation sickness was one factor to which much attention was given. It was studied and treated in various stages to determine the best methods of therapy. It was not the intention to kill a large number of animals, since dead animals would be of little use for study. Particular stress was laid upon the radiation-sick animals, since these were considered of greatest value to medical science for the careful study of their conditions and treatment.

Some of the goats tethered on deck were covered with various types of clothing so that the thermal effects could be decided after direct exposure. Other goats were clipped to hair lengths comparable to humans and protected by various types of anti-flash creams (Figure 4). Such agents must do a manifold duty, for at the instant of the blast X-rays, ultraviolet light, visible light, and heat rays present problems of varying magnitudes, not to mention the corpuscular radiations such as neutrons and beta particles.

It has been said that the atomic bomb tests, with the concomitant destruction of fish and other life, make for a controlled experiment in evolution. The ecology—the equilibria of fauna and flora in nature—of the atoll and its waters and atmosphere may have been completely altered by the bursts, so it is a matter of great interest to know how long it will take to revert to the pre-bomb status.

An extensive fish survey was made at Bikini. This resulted in the collection of 5 tons of fish, including dog-toothed tuna, black and oceanic skipjack, barracuda, uluas, sea bass, wahoo, and red snapper. Several thousand specimens were collected by rotenone poisoning. Others were caught by hand lines, nets, and spears (Figure 5). The objectives of the fish studies were to determine the mortality among fish population after the explosions, the effect of the explosions on different species in the lagoon and along the shore, as well as the migratory fish surrounding the lagoon. The determination of delayed mortality from radioactivity, and the rate and extent of repopulation through reproduction and immigration were also among the objectives.

Neither of the explosions appeared to be highly destructive of fish life in the lagoon, if immediate shipboard observations are any criterion. From the *U.S.S. Panamint* no dead fish were seen floating after the air burst, though three were seen two days before. After the underwater test there were some dead fish 2 to 4 miles northwest of the target, and others were picked up by monitoring parties. Three days after the underwater explosion, within the mouth of Bikini lagoon, two very lively schools of fish were observed by passengers of the *U.S.S. Panamint*, one of large fish feeding on a school of much smaller ones.

Aside from the probability that many fish ultimately became temporarily radioactive, especially after the second test, it is interesting to note that certain algae also acquired a degree of radioactivity which necessitated, in one instance at least, scraping the sides of the ship on which they had grown.

Other tests were made upon vaccines, viruses, toxins, antisera, bacteriophage, hormones, vitamins, and various antibiotics. The effects upon medical and dental equipment were also studied. Packets containing different species of grain were exposed to the direct effects of the blast. When these and other seeds are germinated startling results are not improbable. The genetic effect upon insects in the grain was a matter of interest. The irradiation of living bacteria, both pathogenic and non-pathogenic, should eventually provide very useful knowledge. This will probably be especially true of the micro-organisms upon which rests our present knowledge of the production of and utilization of antibiotics such as penicillin.

Figure 5. Landing a Tuna for the Fish Survey Unit