

# The Able-Baker-Wh

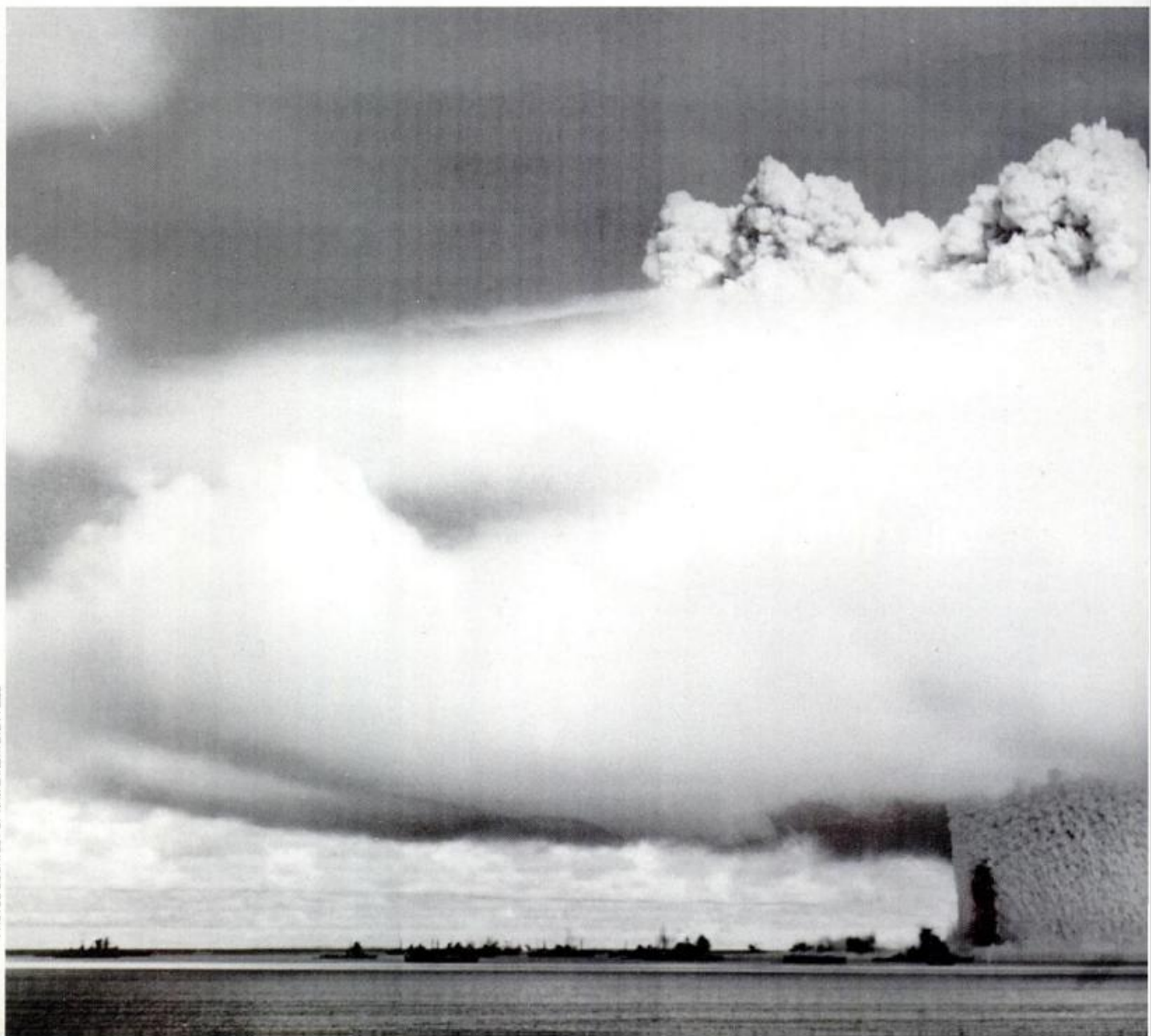
Introduction by MIKE MOORE

In 1946, underwater atom bomb test "Baker" threw a mile-wide dome of water into the air. After the water collapsed back into Bikini Atoll, 86 of the 95 "target" ships were contaminated.

Shortly after World War II ended, the war between the army and the navy resumed. Combat between the two forces in the halls of Congress and on newspaper editorial pages had a long if not particularly distinguished prewar history. For decades, each service had presented itself as more essential to the nation's defense than the other and therefore more deserving of public affection and taxpayer funds. But until August 1945, neither service had ever won a

decisive victory over the other.

But overnight, it seemed, the atom bomb had tipped the balance, putting the navy on the defensive. The Bomb, often spelled with a capital letter, had become the weapon of the future, one that was uniquely suited to the Army Air Forces. Atom-bomb-equipped heavy bombers, not the navy, would become the nation's first line of defense. Their offensive power would deter war. In Congress and on editorial pages, naval armadas had become



# ere's-Charlie Follies

an anachronism, sitting ducks to a future adversary's atomic weapons, if war came.

Naval officers would have none of that sitting-duck business. They did not believe that their beloved cruisers, battleships, and aircraft carriers could be sunk by a nuclear blast, unless the unfortunate vessel was at Zero-point. After all, fighting ships were built to withstand explosions; unlike land structures, they could roll with the punch. But the navy had to convince Congress and the public of

that truth—otherwise, the navy would be in for some very lean times.

Within weeks of the bombing of Hiroshima and Nagasaki, naval officers were beginning to advocate some sort of a test in which an atomic bomb would be pitted against a guinea-pig fleet. After the smoke cleared, everyone would see just how tough those guinea pigs were and how important it was to handsomely fund a nuclear-age navy.

Operation Crossroads, at which the first

**The story of Operation Crossroads is a sad tale of U.S. naval arrogance . . . and ignorance.**



post-war nuclear tests were conducted, became at times a circus, a farce, a near tragedy, and a radio show broadcast live around the world. It was a joint army-navy exercise conducted in the Pacific at Bikini Atoll. It involved 42,000 men, and its ostensible purpose was to evaluate the effects of nuclear weapons on modern naval vessels so that design improvements could be made. In fact, Crossroads was mainly a public relations exercise to which reporters, newsreel cameramen, congressmen, and U.N. observers were invited.

In general, Manhattan Project scientists distanced themselves from the tests. Crossroads would have no scientific value, they argued. And, too, the navy was right—and that was dangerous. Very few ships would be sunk; because of that, the public might come to believe that atomic weapons were not so bad after all. Manhattan Project scientists, many of them at least, wanted people to believe that nuclear weapons were so terrible that they must be outlawed or brought under international control.

Finally, the atomic scientists noted that the tests were designed to measure the wrong thing. Of course, ships were blast resistant—but crews were not radiation resistant. The target ships in Crossroads would have no crews. In a real war, most ships would survive a nuclear attack,

but their crews would die of radiation poisoning.

Even at Crossroads, warned some Los Alamos scientists, radiation would present a significant hazard when crews tried to board the target ships to sail them back to their home ports. The underwater test was likely to throw up a radioactive mist that would contaminate the ships. The navy brass shrugged off the warnings as alarmist and made no decontamination plans.

Three tests were scheduled—Able, Baker, Charlie—all under the command of Vice Adm. William H. P. Blandy, deputy chief of naval operations for special weapons. Able, an air shot on July 1, 1946, disappointed many observers. Most of the 95 target ships escaped with little damage; only five were sunk. Shot Baker, an underwater explosion, came on July 25.

“In one second,” writes Jonathan M. Weisgall, “an underwater bomb pushed a one-mile-wide dome of water into the sky. Ten seconds later, as if in slow motion, the millions of tons of water and debris collapsed back into the lagoon, creating a gigantic curtain of mist and spray that moved outward at more than 60 miles an hour and soon engulfed almost all of the target ships.” The scene has become *the* archetypal nuclear blast, the one that all of us have seen in newsreels and documentaries. It closes

the classic Stanley Kubrick film, *Dr. Strangelove*. All but nine of the target ships were contaminated. In a rare exercise of good sense, Shot Charlie was cancelled.

The story of Crossroads is definitively told in a just-published book by Weisgall called *Operation Crossroads*, an excerpt from which begins on this page. Weisgall’s book is a highly detailed account of a bizarre episode at the dawn of the atomic age, of an experiment gone wrong, and of soldiers and sailors who were exposed to excessive radioactivity because of poor leadership and even poorer planning. There are no heroes in *Operations Crossroads*, although the chief radiological safety officer, Col. Stafford Warren, exercised a higher degree of caution and common sense than most of Crossroads’s line commanders.

The book *Operations Crossroads* is more than a tale of what happened in the summer of 1946 in the far Pacific. It is a graceful and passionate morality play about hubris and folly, whose truths are as relevant to an understanding of Imperial Rome as they are to analyzing mid-century America. At one point, Weisgall quotes Bob Hope, who, in a throw-away line, summed up the meaning of Crossroads as well as anyone: “As soon as the war ended, we located the one spot on earth that hadn’t been touched by war and blew it to hell.”

## By Jonathan M. Weisgall

**T**he amount of radioactive material that collapsed back into Bikini’s lagoon moments after the Baker shot was simply staggering. Unlike the Able blast, the fission products at Baker did not dissipate in the atmosphere. The water surrounding the bomb trapped most of the radioactive material and rained it down over the target vessels. As much as half the bomb’s fission products remained in the lagoon’s water or in the mist remaining in the air after the surge of spray fell back into the lagoon.

Scientists knew from studies of radium-dial workers that only a few millionths of a gram of radium lodged

within human bones could prove fatal. Plutonium, the main component of the Baker bomb, has the same effect and is even more toxic. Test Baker, though, did not involve millionths of grams of radium, or even hundredths of grams. It created the equivalent of *thousands of tons* of radium. Within one hour of the blast, radiation levels in Bikini’s lagoon reached the approximate equivalent of 5,000 tons of radium, which is 1 billion times the radioactivity from just one gram of radium.<sup>1</sup> Initial dose rates on the decks of target vessels closest to the blast exceeded 8,000 roentgens per day, 80,000 times the daily tolerance standard and 20 times

more than a fatal dose.

During the first hour, wrote Ralph Sawyer, Crossroads’s technical director, “the radiation was roughly equivalent to that from several thousand tons of radium.” Even an hour after the shot the target ships a mile from Zeropoint showed a dose rate of 1,200

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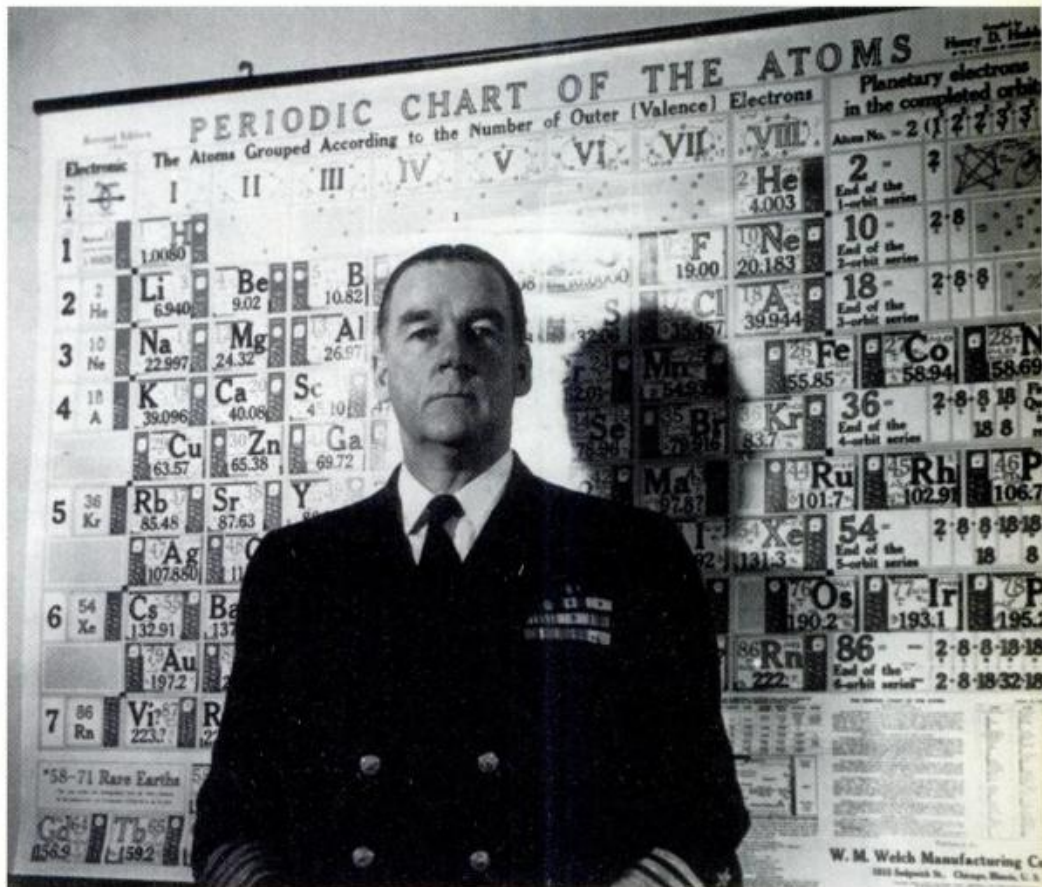
*Copyright (c) 1994 by Jonathan M. Weisgall. From Operation Crossroads: The Atomic Tests at Bikini Atoll, Naval Institute Press. Jonathan Weisgall is a Washington, D.C., attorney and adjunct professor of law at Georgetown University Law Center. He has served as legal counsel for the people of Bikini since 1975.*

roentgens per day, more than three times the lethal dose, meaning that the daily tolerance dose would be reached in seven seconds.<sup>2</sup>

The difference between dose rate and dose is similar to the difference between what is measured by a speedometer and an odometer. Dose rate measures intensity of radiation at any given moment in time, just as a speedometer measures speed at any given moment. Dose measures cumulative radiation exposure resulting from various dose rates, just as an odometer measures cumulative miles traveled at different speeds. Thus, to say that a dose rate of 1,200 roentgens per day on a target ship was three times the lethal dose means that someone would receive a cumulative dose of 1,200 roentgens by staying in that place for 24 hours. Even staying in that location for one minute would result in a dose of 0.83 roentgen (1,200 divided by 24 divided by 60), or more than eight times the daily tolerance dose of 0.1 roentgen.

Stafford Warren's radsafe (radiation safety) section had warned that Baker could cause severe contamination in the lagoon and that the target ships "may remain dangerous for an indeterminable time thereafter."<sup>3</sup> Virtually all of these warnings were ignored. Despite drone boat readings of 730 roentgens per day near the center of the target array, the first patrol boats reentered the lagoon 41 minutes after the shot to measure radioactivity levels and to retrieve instruments. A salvage group reentered the lagoon less than two hours after the shot, and shortly after that radiological monitors and technicians temporarily boarded 12 target ships to retrieve data and instruments. Ten were declared radiologically safe, and by the end of the day 49 support ships returned to Bikini's lagoon with nearly 15,000 men on board.<sup>4</sup>

The warnings all came true. "About four o'clock," recalled Warren, "I began to notice that the deep-water Geiger counters were showing more circulation near and under the observation fleet. This was horrifying to all these commanders. They had to move the fleet."<sup>6</sup> Some ships moved over toward the Eneu channel, while others moved all the way out into open ocean. The blanket of radioactive mist had contaminated the target ships to



Vice Adm. William H. P. Blandy was in charge of the joint army-navy atomic tests.

a much greater extent than had been foreseen. Adm. William Blandy was cautious in his first message back to the Joint Chiefs: "Detailed examination of target ships may be delayed several days by radioactivity persisting in water and on board."<sup>6</sup>

**T**he day after the blast, Blandy tried to tour the ghost fleet with Stafford Warren, but the frantic ticks of the Geiger counter on their small boat confirmed that the ships were much too radioactive for anyone to venture aboard, and they were forced to retreat in less than 30 minutes. Everyone on deck, Blandy told reporters, would have been "goners—if not immediately, at least later on."<sup>7</sup>

Three days after the shot, several support vessels again had to shift anchorage due to an increase in radioactivity near the target array. As the radioactivity decayed, though, all support vessels returned to their regular berths in the lagoon within a week after the blast, and many would remain there for the next five weeks.<sup>8</sup>

Radiation levels on some of the target ships remained dangerously high even a week after the Baker shot, and boarding these ships was unsafe except for brief visits. Some were so radioactive in the first few days after the blast that the daily tolerance dose of 0.1 roentgen per day was reached in less than a minute. Twenty days after the shot, a pile of sand on one ship gave off a reading of 200 roentgens per day, meaning that a person lingering over a "hot spot" like this would reach his daily tolerance limit in just 45 seconds. About half of the radioactive material produced by the blast remained in the waters of Bikini lagoon, and the largest part of this was on the surface of the water.<sup>9</sup>

To make matters worse, radioactivity in the lagoon's contaminated waters quickly spread to the support ships. Ships use saltwater for many purposes, and planners were concerned that water lines might become contaminated with fission products from the lagoon. The radsafe plan therefore cautioned that no distilling plants, heat exchangers, or other apparatus on the support ships that



In an apparently staged photo, seamen attempt to scrub radioactivity from the *Prinz Eugen*. It was a pointless and dangerous activity. The radioactivity persisted; and in the tropical heat, the men often wore little protective clothing.

used saltwater cooling should be operated after either test until the seawater in the lagoon was declared safe by the radiological safety section.

Nevertheless, one day after the support ships entered the lagoon, Blandy authorized them to operate their evaporators, which distilled seawater for drinking. As a result, every nontarget vessel became contaminated just as the planners had feared, as fission products became concentrated on underwater hulls and in condensers, evaporators, and saltwater pipes.<sup>10</sup>

Despite all the warnings that the highly radioactive column of water would come crashing down on the ships, absolutely no one—not even the radsafe section—had planned for the very disaster that had been predicted with amazing accuracy. As the navy admitted a few months later, “Since the nature and extent of contamination of the targets was completely unexpected, no plans had been prepared for organized decontamination measures.”<sup>11</sup>

For all its thousands of pages of detailed plans, the U.S. Navy managed to expose tens of thousands of men and more than 200 ships to radioactive contamination more than 2,000 miles from decent port facilities without ever having attempted experimentally to irradiate a ship or parts of one to determine how—or whether—a ship

could be decontaminated.

The examination of the target ships—the very reason for Operation Crossroads—could not proceed if the vessels were too radioactive for reboarding and examination. As a result, the science of ship decontamination was born at Bikini lagoon following Test Baker. The first experiment, on July 27, was to wash down the battleship *New York* with saltwater, using the huge fire hoses of the fire fighting vessels.

Then, beginning July 28, the navy began to try to decontaminate the ships using materials already at Bikini or obtainable from Pearl Harbor. It tried detergent action with foamite, soap powder, lye, and even naphtha and diesel oil, dissolving action with hydrochloric and sulfuric acid, and adsorption by flour, cornstarch, and charcoal. Using air compressors, other men blasted the contaminated ships with ground corn cobs, rice, barley, ground coffee, and two products readily obtainable from Bikini—sand and coconut shells. Crews even worked with the tried and true navy method—scrubbing.<sup>12</sup>

None of these measures worked very well. Prolonged washing with an acetic acid solution proved helpful but simply was not feasible for mass application, and the other reagents worked only to the extent that they actually removed contaminated sur-

face paint or corrosion. “When you realize that even a small destroyer . . . had a superstructure that was about three acres,” recalled Stafford Warren, “the job of cleaning the radioactivity off was just impossible.”<sup>13</sup>

“The Navy considers this contamination business the toughest part of test Baker,” wrote the Army Corps of Engineers’ Col. Cy Betts to Kenneth Nichols, Gen. Leslie Groves’s top deputy. “They had no idea it would be such a problem and they are breaking their necks out here to find some solution.”<sup>14</sup>

The radsafe monitors were ordered to be fully clothed at all times, including rubber gloves and boots. They knew the value of protective clothing, but teenage sailors did not. “No one told us about radiation or being exposed to anything,” recalled John Smitherman many years later. “We saw these men coming aboard ship and they had these Geiger counters with them and they were walking all over the ship. They had regular shoes on but they had cloth pulled up over their shoes. . . . I still had on a pair of shorts and my tennis shoes and my . . . little t-shirt with a sailor hat. And that’s all the clothing that I had on me.”<sup>15</sup>

**A**fter the Baker test, over 40 percent of the men at Bikini were assigned to tasks involving decontamination, inspection, or towing or salvaging the target ships, with the brunt of the boarding and decontamination effort being borne by the 8,463 crew members of those ships.<sup>16</sup>

Stafford Warren quickly realized that safety guidelines were not being followed. During hosing-down operations, all personnel on tugs were ordered to stay windward of the target ships to minimize contamination, but it was impossible not to get wet. “We’d have to take the clothes off these people,” said Warren; “their clothes were all contaminated and so was the skin of their back. They would not wear their gloves, so they would get the palms of their hands contaminated. After a week of this, the deck of that tug got so bad we had to put it out of service because it was contaminated enough to be hazardous.”<sup>17</sup>

Another unexpected problem came

from the marine life in the lagoon. One radsafe team cruised around near the target ships after the Baker shot, recording the "hot" readings in the lagoon water. When they moved to "cooler" water, though, their Geiger counters showed that radiation levels below deck did not drop to their lower levels. "It looked as though we were somehow or other contaminated with radioactivity—as indeed we were," wrote one monitor.<sup>18</sup> It turned out that radioactive algae, barnacles, and other marine life that concentrated fission products clung to the ships' hulls below the water line and intensified the contamination problem. "Their hulls were just hotter than a firecracker," recalled Warren.<sup>19</sup>

Three days after the shot, outboard bunks on one support ship showed readings of 0.156 roentgen per day, and evaporator readings were at 0.104—both above the daily limit before men were even exposed to the target ships. "We had to move the bunks away from the hulls so that these boys wouldn't get exposed," said Warren. Later studies showed that some marine organisms can concentrate fission products by a factor of 100,000 times the background level in their environment.<sup>20</sup>

Extensive malfunctioning and breakdowns of the radsafe monitors' instruments only made matters worse. The X-263 Geiger counter, which was rushed into production and never field tested, performed poorly. Worst of all, the X-263 could measure gamma radiation (high energy rays such as X-rays), but it could not measure alpha radiation from extremely dangerous substances such as plutonium, and its measurements of beta radiation were often misleading.

"I am not an alarmist, Colonel Warren," radsafe monitor Dr. William Myers wrote. "Probably no permanent radiation injury was sustained by any of the participants. I do believe, though, that many of us probably received much more penetrating, ionizing radiation than the instruments of very low beta-sensitivity were able to record."<sup>21</sup>

Warren agreed. Despite Blandy's assertion that no radiological safety risks would be taken in this peacetime operation, Warren replied to

Myers that Operation Crossroads "was conducted as an emergency and a lot of compromises were made to meet this emergency." Warren knew all too well that Test Baker was a radsafe disaster. "I don't believe you are an alarmist," he told Myers, "but I never want to go through the experience of the last three weeks of August again."<sup>22</sup>

A government report later confirmed that Warren's task force had several instruments for measuring alpha contamination. "None, however," it noted, "proved reliable for field surveys."<sup>23</sup> The extent of beta measurements was stated bluntly in another report: "Little effort was made to measure beta radioactivity."<sup>24</sup>

A large part of the problem was caused by the shortage of overworked monitors.

The peak strength of this group was 350 men, but only a maximum of about 150 was available on any one day to monitor decontamination efforts. The remaining personnel had to measure film badges, analyze water samples, maintain and repair the monitoring instruments, and carry out other technical and administrative duties. The 381 monitors available for the Able shot were just enough to meet the requirement, Blandy later wrote, but for Baker there was a "severe shortage."<sup>25</sup> "Those who have participated," Warren wrote Blandy, "have been worked hard for days and nights and they are approaching physical exhaustion."<sup>26</sup> There was virtually no monitoring of nontarget vessels, and hazardous conditions sometimes went unnoticed on the target fleet.

David Bradley, a radsafe monitor, tried to see the situation from the navy's perspective. "The whole business must seem like a very bad dream to the regular navy men," he wrote. "Decks you can't stay on for more than a few minutes but which seem like other decks; air you can't breathe without gas masks but which smells like all other air; water you can't swim in, and good tuna and jacks you can't eat. It's a fouled-up world."

And into this world had come the radsafe monitors. One afternoon Bradley was assigned to survey the *New York*, whose decks had been sluiced with water, washed with soap, alkali compound, and lye, and then washed again. Radiation levels, though, remained dangerously high. The cap-



In 1943, Gen. Leslie Groves, chief of the Manhattan Project, chose a leading radiologist, Stafford Warren of the University of Rochester, to be his top medical adviser. At Crossroads, Colonel Warren had veto power over the actions of military men who outranked him by several grades.

tain was "completely bewildered," wrote Bradley. "The deck was clean, anybody could see that, clean enough for the Admiral himself to eat his breakfast off of. So what was all this goddamn radioactivity?"<sup>27</sup>

**A**s the days passed after the Baker shot, the captains of the target ships became increasingly upset with Stafford Warren. "Everybody is sitting around . . . staring us in the face and saying 'when can we get aboard,'" he wrote his wife. "They wanted their ships back," he later recalled, despite the fact that they were highly contaminated and no one could go aboard for more than a few minutes at a time. "Well," remembered Warren, "time passed and ships sunk. The *Saratoga*, of course, was the most bitter one, because the navy was convinced they could save her if they had only been able to get close to her."<sup>28</sup>

Admiral Blandy announced several days after the test that the carrier *Independence* would go to Pearl Harbor, adding that her crew wanted to take her all the way to the U.S. mainland under her own power, just to show how much punishment the ship could absorb and still function. Rear Adm. Thorvald Solberg, who was in charge of salvaging the target ships, shared this view; he expected that the decontamination measures would reduce radiation levels to the point where they could return to home ports under their own power. Warren, for his part, confiscated Solberg's radioactive shoes and all the personal

belongings from the captain's cabin on the *Prinz Eugen*—even his clothes and family photographs. Navy pride was in conflict with the demands of radiological safety.<sup>29</sup>

One afternoon Blandy, who was caught in the middle between Warren's concerns and the navy's increasingly angry sailors, ordered Warren to report to the *Wichita*, one of the support ships. "You could just feel a kind of a wall of hate when I walked in," Warren later related. "The tension was just terrific." In front of 1,400 officers and sailors, Blandy said, "Doctor, would you take the microphone and explain to the officers and men what you're trying to do."

Warren explained that his orders from Blandy and President Harry Truman were to protect the men from radiation hazards, which were everywhere in the lagoon. His words fell on deaf ears. The captain of the *New York*, recalled Warren, "was just madder than he could be, because he had his 1,200 or 1,400 men sitting in a barracks ship . . . in that heat. There was his ship undamaged, but contaminated. I wouldn't allow him on board but twenty minutes, and I wouldn't clear his ship for occupancy. I was just a dirty stinker, you know. . . . It was all my fault."

The captain challenged Warren's radsafe measures. "He almost said, 'Any fool knows,' but he said, 'Most everybody knows that radiation varies inversely as the square of the distance, but your men go around and some of them put the Geiger counters three or four inches from the deck, some hold it hip high and use any

kind of way of doing it; there are no standards.'"

Warren did his best to field the criticisms. "I had it hot and heavy for an hour." Blandy closed the meeting, but the tension with the officers remained. Warren's colleague George Lyon, who headed the nonradiological safety team, wrote about one captain "who insists on a 'hairy-chested' approach to the matter with a disdain for the unseen hazard, an attitude which is contagious to the younger officers and detrimental to the radiological safety program."<sup>30</sup> The navy simply did not accept this talk about radiation, and it took Warren, a strong, vigorous, and honest man, to try to keep matters under control. "He was persuasive as hell," recalled one radsafe monitor. "He had to be. He was the only Army Colonel who ever sank a navy flotilla."<sup>31</sup>

**A** host of factors—lingering radiation on the target and nontarget ships, malfunctioning radsafe equipment, a shortage of monitors, failure to observe radsafe regulations, and the ignorance and indifference displayed toward the radiation hazard by officers and enlisted men alike—caused many Operation Crossroads participants regularly to receive radiation doses in excess of the daily tolerance dose. The anecdotal evidence is simply overwhelming. The radsafe section detected 67 overdoses between August 6 and 9, with some men exposed to 20 times the daily tolerance dose. Less than a week later, Warren reported that 26 of the 125 film badges showed overexposures, with 13 over twice the daily tolerance standard.<sup>32</sup>

All decontamination work on two target vessels, the destroyer *Wainwright* and attack transport *Carteret*, was stopped due to the crew's overexposure from working and living on the ships: the crews were immediately evacuated to the United States. Similar examples abounded throughout the task force; not even the scientists and technicians were spared. "There were people, particularly the scientists, who thought they knew better," recalled Warren. "I had to send some home because they were already overexposed—not badly, but



The decks of the *New York* were sluiced with water, washed with soap, alkali compound, and lye—but still remained dangerously radioactive.

beginning to be questionable."<sup>33</sup>

To make matters worse, individual officers extended the crews' working hours on target ships without consulting radsafe monitors. "It appears that there is an attitude of indifference on the part of the ship's officer of the *Prinz Eugen* to the safety standard set by RadSafe," wrote two of Warren's men, who found readings of 5 roentgens per day on the superstructure, 50 times the maximum daily tolerance dose. Nevertheless, crew members stayed on board the ship for as much as 16 hours or more. Some were ordered to spend the night there, because the ship's officers believed that the daily tolerance dose "has such a large safety factor that it can be ignored."<sup>34</sup>

The radiological crisis developing at Bikini was made more acute with the daily departure of radsafe monitors. "Monitoring demands have been increasing steadily while our numbers are being depleted," Warren wrote to Blandy on August 7. "Attempts to delay these men have met with unanimous refusal." He was going to lose more than 90 percent of his men in the next week, leaving him with only a handful of monitors to protect the crews working on more than 70 target vessels. He also recognized the difficulty of enforcing radsafe regulations. "It is almost impossible to enforce the wearing of gloves continuously on badly contaminated ships," he reported. "Nor is it feasible to expect [men] to take the proper care of their contaminated clothes."

Film badges, which were radiation-recording devices, were not designed to measure beta radiation. Warren's Medico-Legal Board, a hand-picked group of experts advising him on radsafe measures, assumed a 5 to 1 ratio between beta and gamma radiation, but the actual ratios varied widely and were much higher, probably 10 to 1. "Contamination of hands and faces with beta emitters of intensities greater than tolerance . . . is exceedingly common," Warren warned two weeks after the Baker shot. "It is not infrequent to find personnel with amounts on the bare hands bordering on erythema dose levels"—a reddening of the skin caused by a dose of 300 roentgen or more.<sup>35</sup> Only about 6,300 of the 42,000 Operation Crossroads participants were issued film badges,

and no one, except perhaps for a few radsafe monitors, wore a badge every day.<sup>36</sup> Moreover, the information obtained from them was only available after exposure had occurred and thus did little to warn or protect the men, a point not lost on the wearers. Told by a radsafe monitor that the film in his badge was exposed like X-ray film to determine "how much you've been getting," one sailor replied, "Sure, but that only tells you afterwards. A lot of good that is when you've been fried all day in X-rays."<sup>37</sup>

**W**arren was most concerned about alpha emitters such as plutonium. Alpha particles pose little threat outside the body and can be blocked by even a sheet of paper, but once absorbed they can be lethal. Setting safety standards for plutonium at Los Alamos during World War II was pure guesswork. Like radium, the new element proved to be a bone seeker, but its alpha emission seemed to be smaller. Guessing that the body could bear up to 100 micrograms of plutonium, the Manhattan Project at first set 5 micrograms as the tolerance dose, 50 times the dose for radium.

Further studies, however, showed that plutonium was eliminated from the body at a much slower rate than radium, and it seemed to be five or 10 times more toxic than radium despite its lower alpha activity. This led Manhattan Project scientists to lower the tolerance dose fivefold to 1 microgram, but the war ended with little knowledge about the behavior of plutonium in the lungs and elsewhere in the body. Moreover, although scientists had developed instruments to measure beta and gamma activity, they had no reliable field instruments to detect and measure alpha activity.<sup>38</sup>

Warren's Medico-Legal Board concluded three days before the Baker shot that the amount of plutonium would be "so small as to be un-hazardous," but this was not the case.<sup>39</sup> "In truth, we were grasping in a field that was new," recalled Robert Conard, a radsafe monitor who later worked on radiological conditions in the Marshall Islands. "We had no way of accurately assessing how much plutonium was present, so we relied



Radiation monitors pose for the camera.

almost exclusively on beta and gamma monitoring."<sup>40</sup>

Two weeks after the test Warren noted that many ships had beta and gamma intensities low enough in places to lead some monitors to think the ships were safe. "This is not the case," Warren warned bluntly, because of the "widespread presence" of alpha-emitting plutonium in the target area. "It accompanies the gamma and beta emitters everywhere in a definite proportion," he explained, "and the presence of beta emitters in even moderate intensities is an indication that it is present in dangerous if not lethal doses."

Moreover, he said, accurate detection and thorough decontamination were not possible. "It can only be measured with very precise equipment which is not available and cannot be made available," he wrote, adding that "decontamination requires meticulous care and an elabo-

rate set-up of equipment and trained men, none of which are available."<sup>41</sup>

And even though gamma readings were declining, they were still high even 10 days after the test. Thirty-five target ships still had average topside readings more than 10 times greater than the daily tolerance dose, and some, such as the *Pensacola*, had an average daily reading 70 times greater. Nevertheless, for weeks after the tests men routinely boarded target ships, swept them, scraped them, ate their meals on board, and even slept aboard them; they were constantly exposed to the danger of inhaling plutonium and fission products from the Baker test.<sup>42</sup>

**O**n August 3, nine days after the Baker shot, Warren was convinced he had a disaster on his hands. Declining gamma readings resulted in more pressure from captains to return their men to the target ships, but this did not mean the plutonium situation was any better. He warned that decontamination efforts were largely useless. "No practical method of decontamination is known in the case of wooden surfaces and rough metal short of removal of the actual surface," he said, adding that there was "increasing evidence" of exposure well over the daily tolerance dose.

Warren was also worried about the daily tolerance dose of 0.1 roentgen as a limit for long-term exposure. He told Blandy that as little as half that level of daily exposure for three months "may cause progressively increasing sterility . . . which upon disappearing may still result in defective children," and that such daily exposure for even less than three months "may cause defects in children of the first and second generations."

Warren realized that several more weeks of continuous exposure would be disastrous. "The majority of personnel exposed at Bikini are young," he wrote, "and their heredity is of prime importance to them and their families."

Warren urged Blandy to end Operation Crossroads immediately, except for work on target ships with relatively little radioactivity. All the other ships, he recommended, "should be declared hopelessly contaminated

and be towed to shallow water and beached and time allowed for radioactive decay to take place."<sup>43</sup>

The Medico-Legal Board met the next day and agreed with Warren's recommendations, but Rear Adm. Thorvald A. Solberg, who was in charge of salvage operations, insisted that work was proceeding satisfactorily. Blandy sided with Solberg. "Admiral Blandy would not go along with Warren's recommendation to close out altogether," wrote one participant. "He insists on continuing a program of decontamination no matter how long it takes."<sup>44</sup>

Blandy was unwilling to admit that so many ships were contaminated, and he was concerned about the public relations aspect of what he called the "hot" ships. "These ships must not be considered as casualties in the sunken ship sense of the word," he said at the August 6 staff meeting, and he ordered that ships sunk or destroyed more than 30 days after the Baker shot "will not be considered as sunk by the bomb." Like Solberg, Blandy was convinced the ships could be decontaminated. "The idea must not be fostered," he told his staff on August 6, "that nothing can be done about the radioactive condition of the ships."<sup>45</sup>

Warren did not let matters rest there. "Control of the safety of the target ships' crew is rapidly getting out of hand," he asserted bluntly the next day, August 7. "The target vessels are in the main extensively contaminated with dangerous amounts of radioactivity. Quick decontamination without exposing personnel seriously to radiation is not possible under the present circumstances and with present knowledge." He was also alarmed about the state of his men and their equipment and he called for an end to Operation Crossroads by August 15. "No further gain can be obtained without great risk of harm to personnel engaged in decontamination and survey work."<sup>46</sup>

Blandy reacted cautiously, taking no definitive action, but he was beginning to understand the magnitude of the problem. On August 8 he sent a cable to Washington asking Adm. Chester W. Nimitz, the chief of naval operations, to allow him to decommission 39 target ships. "They cannot all be made absolutely safe to board in

the near future for sufficiently long periods to either prepare them for movement to Pearl [Harbor] or to assess fully the damage sustained," wrote Blandy.<sup>47</sup>

The turning point came on August 9. Lt. Commander William A. Wulfman, a physician in charge of the target ships' rad-safe monitors, wrote Warren that "work on target ships has increased to the point that it is impossible to provide adequate protection for the personnel involved in this work." Wulfman, too, realized that many men had received doses well above the daily tolerance of 0.1 roentgen.<sup>48</sup>

On that same day, Blandy finally realized that Geiger counters could not detect plutonium, as Solberg asked Warren to inspect and measure radiation levels on material obtained from the wardroom of the *Prinz Eugen*. Geiger counter readings showed radiation intensity sufficiently low to permit men to spend long periods of time on the ship without danger of injury, but other tests on more sophisticated instruments showed what the navy later described as "widespread presence" of plutonium. The few instruments capable of detecting alpha radiation at Bikini could not operate outside the controlled laboratory conditions on board the *Haven*, the ship housing Warren's radiological safety section.<sup>49</sup>

Later, on August 9, following a conference aboard the *Haven* with Commodore William S. Parsons, Warren sent a teletype message to the Manhattan Project stating that an "urgent need exists for radiation measuring instruments." He ordered 300 X-263 Geiger counters, 100 dosimeters, 18 ionization chambers, six beta counters, and 50,000 film badges. "Strongly urge that . . . this [be] treated as an actual emergency involving safety to life," he teletyped.<sup>50</sup>

Blandy called a meeting for August 10 to discuss Warren's findings. Warren's chief adversary remained Admiral Solberg, the head of salvage. "It was his group of ab[ou]t 2,000 men whom I was fighting," Warren wrote his wife. "He felt he could clean up these ships & I'd been saying he was butting his head against a stonewall & was only fooling himself & risking a lot of men."

Parsons had seen the results of

analyses flown in from Los Alamos just before the meeting. "This stops us cold," he told Warren, and supported him fully. Warren showed Blandy how alpha emitters in the scales of a fish created an X-ray picture when placed on photographic film. Blandy respected Parsons's judgment and said simply, "If that is it, then we call it all to a halt." Decontamination efforts were considered unsafe under the existing conditions, and Blandy ordered all further decontamination work discontinued. Warren was pleased. "A self X-ray of a fish . . . did the trick," he wrote home.<sup>51</sup>

As a result of the August 10 conference, all decontamination work was halted. Undaunted, one ship commander proposed two days later that the external gamma readings were low enough for men to board the bigger target ships in order to start their engines for pumping. "This is not the case," replied Warren abruptly the next day in what a later government report described as a "didactic" memorandum. "The widespread presence of an alpha emitter has been demonstrated," he said, and the request was denied.

Warren also realized that some of the commanders of the target vessels were not complying with the radsafe guidelines, so he simply forbade further work on the ships. Stating that the continued use of crews for decontamination work without proper training and equipment "is exceedingly dangerous," he ordered that men could board the ships only to recover instruments, install pumping gear, and prepare the ships for towing to Kwajalein.<sup>52</sup> Warren's radiological findings were later confirmed by Los Alamos based on analyses of target ship samples that had been flown back to the laboratory.<sup>53</sup>

**F**or Stafford Warren, it was the end of what seemed to be a single-handed battle against the navy. He reported to his wife with near disbelief a few days later that the navy had actually listened to him again. "Recommended today that the area be abandoned by 1 Sept. and they tow the ships they want to Kwaj[alein] & they will do so! If not sooner!" Thousands of Cross-



Washington, D.C., November 7, 1946: Admiral and Mrs. Blandy (with Adm. Frank J. Lowry) celebrate the dissolution of the Crossroads task force by cutting into an atom-bomb cake. Any similarity between the cake and Mrs. Blandy's hat is believed to have been coincidental.

roads personnel began leaving Bikini within days, including Warren.

Warren, who was given a "Mark III" lead jockstrap by his staff to celebrate his fiftieth birthday at Bikini, was completely exhausted and slept off and on for four straight days. He also had time to reflect on the tests, and he hoped that the navy might have finally developed a healthy fear of the bomb. "I think the navy now has an idea, a very little idea of what a scourge it can be and what a boomerang," he wrote home.<sup>54</sup>

By early September the last ship had left Bikini, and the atoll was completely evacuated by September 26. For security reasons, some of the evidence was destroyed.

Most of the physical evidence, though, remained. More than a dozen ships now rested on the lagoon floor. The steel towers that had mounted high-speed cameras still stood, as did the concrete basketball courts, dispensary, and baseball fields. The story of Operation Crossroads was also evident on the lagoon side of the small islands in the western part of the atoll; beaches were strewn with

oil drums, mattresses, bottles, tires, boxes, and rusting machinery, all smeared with tar and oil.

Flying at the edge of the cloud after the Baker shot, David Bradley's Geiger counter clicked wildly and the needle showing levels of radiation went off the scale. "It always seemed a little strange to me," he wrote, "that at such a time the pilot should be calmly looking down at the fleet, or glancing over his instrument panel. . . . Something was wrong. We should be able to feel the barrage of gamma rays tearing through our bodies. It was there. It was hot."<sup>55</sup>

The greatest danger of atomic warfare lay not in the immediate blast and heat from the atomic bomb but from the deadly lingering radioactivity. However, as E. B. White put it, the navy "is contemptuous of anything that isn't big and noisy and that refuses to come out in the open and fight."<sup>56</sup> The ghost fleet would not sail back under the Golden Gate Bridge, triumphant and invincible. The ships survived their familiar enemies of heat and blast, but the navy had never fought an alpha particle. ■

(Footnotes, overleaf)

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