

International Radiation Research and Training Institute (IRRTI)

IRRADIATION OF PERSONNEL DURING OPERATION CROSSROADS:

AN EVALUATION BASED ON OFFICIAL DOCUMENTS

BY

DR. ARJUN MAKHIJANI

AND

DAVID ALBRIGHT

MAY 1983

**317 Pennsylvania Avenue, SE
Washington, D.C. 20003
USA
Tel: 202/544-2600**

Reply to US address

**IM SAND
D-6900 Heidelberg 1
West Germany
Tel: 06221-12956 + 10101**

**26 Fellows Lane
Harborne, Birmingham
17 England
Tel: 021-472-7752**

**Dept. of Radiological Health
c/o Dr. Ikuro Anani
Faculty of Medicine
University of Tokyo, 113
Bunkyo, KU
Japan**

PREFACE

This report is based on official documents of Operation Crossroads. Most of them are those of the late Colonel Stafford L. Warren who was the Chief of the Radiological Safety Section during Operation Crossroads. He had donated the declassified (formerly secret and top secret) papers to the library of the University of California, Los Angeles. Anthony and Mary Guarisco painstakingly went through them, sifted them and made copies available to us. Without their initiative, insight and work, this report would not have been possible. Walden Bello also provided some useful materials.

Dr. Karl Z. Morgan reviewed it and, as a scientist who was present at Operation Crossroads, provided many useful comments, insights and details. E. Cooper Brown, Glenn Alcalay and Kathleen Tucker also gave us useful comments and editorial help. Besides reviewing it, Bob Alvarez also arranged for us to work on this as a joint project. Lewis Wood and Diana Kohn typed it. We thank them all.

Chapter I

Summary and Conclusions

"Col. Fields said that Gen. Groves [the director of the Manhattan Project which made the first atomic bombs] is very much afraid of claims being instituted by men who participated in the Bikini tests."

Decontamination Report

The official documents of Operation Crossroads, which consisted of two atomic bomb tests, show that it was conducted in a manner which was grossly negligent regarding radiological safety for the 42,000 people who witnessed it. Conditions were particularly bad in regard to the second atomic test, named "Baker," on July 25, 1946.*

Test Baker was to be the first ever underwater explosion. Conditions were therefore particularly uncertain. The Radiological Safety Section had predicted that if the radioactive "column" from the explosion did not rise more than 10,000 feet -- as was in fact the case -- that radiological conditions would be "extremely serious." It was further predicted that the radioactive spray would utterly contaminate the target ships which "may remain dangerous for an indeterminable time thereafter."

The commanders responsible for the tests paid little heed. "Since the nature and extent of the contamination was completely unexpected," states the Decontamination Report written afterwards, "no plans had been prepared for organized decontamination measures." The documents confirm

*This report evaluates conditions on and after July 25, 1946, since the documents we have relate to that period. Most of them came from the papers of Col. Stafford L. Warren, a physician, who was the Chief of the Radiological Safety Section at Operation Crossroads.

that a cavalier attitude toward safety prevailed among many of the officers who "insisted on the blind 'hairy-chested' approach to the matter [of radiological safety] with a disdain for the unseen hazard," according to Capt. Lyon of the Radiological Safety Section.

Test Baker sent up a million-ton column of radioactive water, spray and steam about 6,000 feet high which came raining down on Bikini lagoon and the target ships, irrevocably contaminating almost all of them with the products of atomic fission and with plutonium, considered then as "the most poisonous chemical known."

On the very day of Test Baker, men were sent into the radioactive lagoon and the beaches to measure radioactivity and retrieve instruments. Within three days, they were also sent on highly radioactive ships to measure radiation and to retrieve equipment, instruments and experimental animals. All the non-target ships on which the men lived and worked were moved into the radioactive lagoon (some as early as the day of the test itself), and subsequently became contaminated. This action occurred in spite of Col. Warren's warning of "the possibility of an indirect hazard due to the concentration of radioactive products..."

Decontamination efforts were started on intensely radioactive ships even though "no one as yet know how to decontaminate" a ship. The Department of Defense exposed about two hundred ships to contamination at Bikini, thousands of miles away from substantial port facilities, without ever attempting to experimentally contaminate and then decontaminate a single ship! In spite of this admitted ignorance, men were exposed to the extreme dangers of attempting to decontaminate the target ships -- a futile effort which eventually had to be abandoned because of severe radiation hazards, and many of the ships were eventually sunk.

The operation subjected the personnel to large, and in some cases, increasing radiological dangers. Col. Warren noted that "contamination of personnel clothing, hands and even food can be demonstrated readily in every ship...in increasing amounts day by day." (Emphasis added)

There was a "widespread presence of an alpha emitter [plutonium] in the target area." Yet, "no alpha detectors for general field use were available." Little protection from inhalation or ingestion of this most deadly chemical was given to the men. Yet after shot Baker it was present on the ships' surfaces, in the evaporators, in the spray and mist which resulted from cleaning the target ships. Similar dangers existed with respect to the fission products.

Even in the case of gamma radiation (which is like X-rays), the radiation levels on the ships varied considerably and were intense in many places. Merely "lingering" in a place with high radiation for a few minutes could cause a dose ten times the daily "tolerance" limit.

As a result, it was common for men to be exposed over the daily "tolerance" limits. Men who slept aboard some target ships like the New York could have received 20 times the "tolerance" limit of 0.1 roentgen per day during a night. Linger in a "hot-spot" whose locations were often unpredictable could cause the daily exposure limit to be reached in 45 seconds. Col. Warren found it "exceedingly common" that beta radiation doses to hands were above standard and "not infrequent" that they bordered on the erythema dose of 300 rads. We must note here that even the "tolerance" dose was very high by today's standards. According to Dr. Warren, the intermediate dose calculation on which it was based was "pure guess." As a result, these limits for industry were repeatedly lowered so that

they are today about one sixth of the value adopted then (on an annual basis). The "tolerance" limits at Bikini were more than 5,000 times the allowable limit of 5 millirems per year set by the Nuclear Regulatory Commission for nuclear power plant neighbors.

A great many men did not wear film badges -- the minimal equipment required to measure gamma radiation. The instruments available to the radiation safety monitors were "experimental," many of which "all too often failed to work entirely," and when they did were often "erratic" and "misleading." "I am not an alarmist, Dr. Warren," wrote Dr. Myers, one of the safety monitors. "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."

The radiation dose standards set for the operation were those set by the Bureau of Standards for manufacturing plants. However, with atomic explosions, the conditions obtaining in industrial plants do not apply. The distribution of radiation was erratic and essentially unknowable. For hazards such as plutonium, no field instruments were available at all. Those available were erratic or failed to work entirely. Coupled with the "hairy-chested" "attitude of indifference" to radiation hazards on the part of many officers, it is no wonder that Col. Warren, the Chief of the Radiological Safety Section, exclaimed "I never want to go through the experience of the last three weeks of August [1946] again."

In terms of the hazards to an estimated 250,000 military personnel involved in atmospheric bomb testing, the Defense Nuclear Agency claims that overall "Exposures generally were well within established radiation exposure limits [and] there was no reason to expect any increased health risk."

The documents show that:

- Film badge records often exceeded daily "tolerance" limits.
- The "indifference" of officers to radiological safety led them to keep men for long periods in high radiation areas, often in violation of radiological safety rules and guidelines.
- Radiation instruments often did not work.
- The beta radiation danger was great both from external and internal sources -- it was "exceedingly common" to find dose limits being exceeded.
- Alpha contamination [plutonium] was "extensive and unpredictable" to the extent that "no one can say any place is safe for any length of time."

The Defense Nuclear Agency claims in particular that the "internal doses have proven to be essentially insignificant." Yet the observations above from the documents and Col. Warren's note that "any surface of any vessel may be in fact the residence of many lethal doses" shows that the Agency has not taken the facts into account while making this sweeping generalization. Indeed, it is more than likely that a great many of the men who were made to do work such as sweeping, scrubbing, hosing down decks, scraping and repainting the sides of some ships, inhaled and ingested very dangerous quantities of fission products and plutonium. Even changing clothes and eating was dangerous since fission products were found on clothing, food and hands "in every ship...in increasing amounts day by day."

The documents do not give us sufficient evidence to reconstruct doses. But they do definitely tell us that the Defense Nuclear Agency's claims of generally low doses and "insignificant" internal doses is

without regard to essential facts and hence without scientific merit.

This will continue as long as the Defense Nuclear Agency does not take the testimony of the atomic veterans regarding their activities as fundamental data needed for any and all dose reconstruction exercises.

Chapter II

Operation CROSSROADS: Introduction

"...I never want to go through the experience of the last three weeks of August [1946] again.
..."¹

Col. Stafford L. Warren
Chief, Radiological Safety Section

On July 1st and July 25, 1946, the U.S. Military conducted two atomic bomb tests off Bikini Atoll in the Marshall Islands. The first, Test Able, was exploded in the atmosphere above the lagoon. The second, Test Baker, was exploded underwater, in the lagoon.

Forty-two thousand people (mostly naval, but also Army and Air Force personnel, as well as civilians) witnessed these first atomic explosions after Hiroshima and Nagasaki.² Their purpose, according to the Joint Task Force One that was established to conduct them, was "primarily to determine the effects of atomic explosions against naval vessels" and "secondarily, to obtain as far as practicable the effects of atomic explosives against ground targets and airplanes and to acquire scientific data of general value."³

There were 84 "target ships" positioned around "ground zero" with instruments and animals and about 100 non-target ships. Test Baker was a shallow underwater detonation that sent a million-ton column of water spary and steam shooting six thousand feet up.* This very radioactive water came raining down on the lagoon, the beaches and the target ships and severely contaminated them. The blast precipitated immense waves

*This evaluation of Operation Crossroads is about the period after this second test on July 25, 1946, because most of the documents on which it is based relate to that period.

which further contaminated all these places. Within a few days the non-target ships were moved back into the lagoon. These ships also became increasingly contaminated as radioactive materials were selectively deposited on and in them.

The indications are that the overwhelming majority of people involved received considerable doses of radiation from a number of sources:

- Living and working aboard non-target ships;
- Retrieving experimental animals and equipment aboard the target ships and from the lagoon and beaches;
- Measuring the radioactivity in the area of the explosion and on the target ships;
- Attempting to decontaminate the target ships; and
- Preparing target ships for towing both within the lagoon and out of it.

Other people not present at the tests also no doubt received radiation doses as a result of subsequent experimental and decontamination work at Kwajalein Atoll, San Francisco and other ports. Almost all the target ships were so contaminated that they could not be salvaged and were sunk in deep water.

This evaluation of the radiological conditions at Bikini, their effect on the people present, and the adequacy or lack thereof of the radiation standards is based on the documents prepared by the participants in the test -- principally those of the personnel in charge of the Radiological Safety Section. The documents, which were obtained from the papers of the late Col. Stafford L. Warren, the Chief of that section, show that the manner in which the operations were conducted makes it impossible to

precisely estimate how much radiation the various participants received. However, the evidence, both in regard to the radiation measurements and the conditions of life and work, also shows that it is likely that significant numbers of people probably received very high doses of radiation in tissue destructive ranges.

References to Chapter II

1. Col. Stafford L. Warren, letter to Dr. William G. Myers, December 31, 1946.
2. Joint Task Force One, Report on Atomic Bomb Tests ABLE and BAKER (Operation CROSSROADS), Navy Department, Washington, D.C., 15 November 1946.
3. Ibid., p. 1(A)(1).

Chapter III

Radioactive Contamination and Exposures

"The initial contamination of surfaces was so great that reduction on the deck and other surfaces of 90% or more still leaves large and dangerous quantities of fission [products] and alpha emitters scattered about...

"Contamination of personnel, clothing, hands, and even food can be demonstrated readily in every ship in the JTF-1 [Joint Task Force-One] in increasing amounts day by day."¹

Col. Stafford L. Warren
Chief, Radiological Safety Section

The decision to conduct the atomic explosions Able and Baker was made only about six months prior to the first test on July 1, 1946. Within that time more than forty thousand men had to be assigned to and assembled at Bikini and other preparations, including those for radiological safety, had to be completed.

The conditions for radiological safety were not promising. An atomic explosion had never been set off underwater. In spite of this, the Navy did not attempt to experimentally contaminate and decontaminate a single ship before taking the fleet to Bikini, thousands of miles from any port with substantial relevant supporting facilities.

The radiological safety section had clearly warned of an "extremely serious" situation if the radioactive "column" from Test Baker did not rise more than 10,000 feet -- as in fact did happen. The prediction warned of "most significant contamination due to direct deposition of fission products...in the water of lagoon, on surface ships and in the fallout....On some target ships possibly within 1,000 yards of detonation,

boarding inspection may be dangerous for weeks..."²

The warning of the possibility of serious contamination was ignored by those in charge of the operation, since no preparations for the possibility were made. The official Decontamination Report states:

"Since the nature and extent of the decontamination was completely unexpected, no plans had been prepared for organized decontamination."³

This lack of planning meant that a great many officers were unprepared and did not take radiation safety seriously. They were given little training in such matters. The overwhelming majority of the rest of the 42,000 people received even less. Without a systematic program of radiological indoctrination for the personnel, a staff of less than 400 of the Radiological Safety Section was confronted with an almost impossible task.

Only a handful of these had any experience with radiological safety as it concerned atomic explosions. Many had no prior experience with radiological matters at all, civilian or military. Only thirty three "were given a fairly thorough two and a half month course."⁴ The rest received some training aboard the USS Haven during the four weeks prior to the test.

A. The Contamination of the Ships

"...no one yet knew how to decontaminate..."⁵

Decontamination Report of
Operation Crossroads

Immediately after Test Baker, it became apparent that almost all target ships not sunk by the explosions, as well as the waters of the lagoon and substantial portions of Bikini Island itself, had become severely contaminated. The result of the test corresponded to the most dangerous of the contingencies outlined in the prediction: "Extremely Serious."

In addition to contamination by the radioactive spray and rain, the explosion scoured up coral sand from the bottom of the lagoon which became radioactive and some of which was deposited on the target ships. A pile of sand on one target ship gave a reading of 200 roentgens per day -- two thousand times the "tolerance radiation limit per day set for personnel exposure -- twenty days after the test."⁶ Some materials like wood decks and manila line selectively absorbed radioactive matter. In all these ways the ships became "dangerously hot,"⁷ with the radioactivity spread out very unevenly and unpredictably.

On the very day of Test Baker, non-target boats and ships were sent into the lagoon. And only one day afterwards, the Commander of Joint Task Force One "authorized vessels at anchor in the lagoon to operate evaporators."⁸ At that time, there was not only radiation from fission products and plutonium, but also very intense radiation from sodium-24 and other activation products.* This was again in contradiction to the warning in the safety prediction that:

"there is the possibility of development of an indirect hazard due to concentrating radioactive products particularly in the form of salts in condensers, evaporators, and perhaps other places on ships entering the lagoon prior to the time that the contamination is greatly reduced. It is very difficult to evaluate the likelihood or the magnitude of this possibility -- but it must be anticipated."⁹

Apparently without checking the non-target vessels already sent into the lagoon for contamination by these means, the rest of the non-target ships were moved into Bikini lagoon to "regularly assigned berths" within

*Some of the neutrons produced by the fission of plutonium were absorbed by sodium rendering it radioactive, which was also true of some other elements in the seawater. These "activation products," particularly sodium-24, were a principal source of radioactivity in the lagoon and on the island for the first two days after Test Baker.

six days of the test.¹⁰ As a result, every non-target ship became contaminated in the manner predicted -- fission products and plutonium were selectively concentrated in salt water pipes, evaporators and condensers. In addition, coral, algae and other organic materials which selectively concentrated radioactive materials adhered to the body of the ship below the water-line, creating a decontamination problem of immense difficulty and danger. In fact, at the time "no satisfactory means of decontamination of underwater bodies and salt water systems in the Bikini area was apparent."¹¹

It was only after the radioactive ships reached San Francisco and other major ports, followed by extensive experimentation and work, that the levels of radioactivity were substantially reduced. In the meantime, the sailors received radiation doses as they lived and worked aboard. In fact, some radioactive ships were cleared for occupancy before decontamination because Operation CROSSROADS had contaminated so many ships that the Pacific Fleet was experiencing shortages. On September 9, 1946, the "Commander Western Sea Frontier" stated:

"Districts have insufficient personnel to effect full clearance of vessels and, furthermore, no one yet knows how to decontaminate. Consequently, several APA's, Destroyer Division 72 and some auxiliaries have been cleared practically to meet operational requirements on the basis that they might as well continue to operate until methods of making them safe for overhaul are developed."¹²

In spite of the fact that no one knew for months after the tests how to decontaminate the partially contaminated non-target ships, attempts to decontaminate the much more severely and extensively contaminated target ships began only a few days after Test Baker.

B. The Irradiation of Personnel

"Every contaminated place as evidenced by the gamma or beta radiation on any surface of any vessel may be in fact the residence of many lethal doses of this alpha emitter [plutonium]."¹³

Col. S. L. Warren
Chief, Radiological Safety Section

The lack of adequate preparation and training of the personnel and the insufficient number of radiological monitors began to be apparent within a few days. On non-target ships Dr. Karl Z. Morgan (Director of Health Physics at Oak Ridge National Laboratory) found that "radioactive salt water was being used to wash meat racks on the USS Sador."¹⁴ On the target ships, the radiation monitors noted the cavalier attitudes of many officers:

"It appears that there is an attitude of indifference on the part of the ship's officers of the Prinz Eugen to the safety standard set by RadSafe. There is reason to believe that men are being kept aboard for longer periods than they should be and also that the standard of 0.1R has such a large safety factor that it can be ignored. Some of the men who were observed to be aboard the ship when we came aboard at 0800, ...were probably on the ship all that night and...until 1200 of the same day."¹⁵

Since some of the radiation levels measured were as high as 5 roentgens per day, which would have given the "tolerance" dose of 0.1 roentgen in about half an hour, some men aboard could have received 2 roentgens or more of gamma radiation during the night. In addition, a handwritten note on the memo says that there was "evidence of dry sweeping and sleeping aboard" the target ships. Sweeping was a hazardous practice because of the heightened danger of inhaling resuspended fission products and plutonium.

Almost a year later, Captain Lyon, evaluating radiological safety in response to a written complaint from Ensign Coffin, noted that there were officers "like Captain Maxwell 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."¹⁶

With this "hairy-chested" approach on the part of many officers, it is not surprising that enlisted men were violating basic radiological safety rules, such as sleeping on board target ships.

All the personnel at Operation CROSSROADS were constantly exposed to alpha, beta, and gamma radiation from plutonium and the other radioactive elements which were the result of the explosion. Alpha radiation consists of two protons and two neutrons tightly bound together (identical to the nucleus of a helium atom) which only penetrate the outer layers of skin. However, alpha emitters like plutonium are extremely damaging, even in microscopic amounts, when they are inhaled or ingested and become part of the body. They can then severely damage the cells around the spot where they become incorporated. Beta radiation consists of electrons, several thousand times lighter than alpha particles, and more penetrating. External beta radiation generally damages cells on or near the surface of the skin. However, beta radiation from some fission and activation products have a range up to one centimeter (0.4 inch) in soft tissue. There is thus the risk of damage to the lenses of the eyes, male gonads, thyroid and some lymph nodes. Beta emitters can be incorporated into parts of the body where they irradiate internally with the possibility of severe damage (e.g., strontium-90 to the bone). External whole body radiation comes

primarily from gamma rays, which are high energy rays like X-rays, and which can penetrate through to various parts of the body. These rays can pass through the body without harming any cells, or kill cells, or damage cells.

C. Gamma Radiation

"It is most likely that a number of persons not carrying film badges were likewise over-exposed."¹⁷

Medico-Legal Board

On the first days after Test Baker, some of the target ships were so radioactive that the "tolerance" dose of 0.1 roentgen per day* would be exceeded in less than one minute. In spite of this, men were sent aboard ships in the first few days after Test Baker. Every one of several hundred test animals had been retrieved by these men within the first five days.¹⁸ Similarly men and boats were sent into the lagoon and onto the beaches to measure radioactivity and retrieve equipment on the very day of the test. The lagoon and the beaches were extremely radioactive not only from fission products and plutonium but also because of the neutron-induced radioactivity in sodium. The gamma and beta radiations from sodium-24 are of very high energies and can cause (correspondingly) greater damage. Organic matter such as ropes and canvas had extremely high concentrations of radioactivity, in many cases "greater than 200 roentgen per 24 hours (the maximum which could be read with the instruments

*A roentgen is a unit which measures ionizing radiation by the amount of air it ionizes. It is no longer in common use, but is approximately equivalent to one rad which is a measure of the amount of radiation absorbed per gram of matter (1 rad = 100 ergs per gram; 1 roentgen approximately equals 93 ergs per gram of soft tissue). The "tolerance" dose on an annual basis was 30 roentgen.

available."¹⁹ It is most likely that many people received extremely high doses to all or part of their bodies near such things.

Similar dangers persisted after the first few days when the average level of gamma radiation had subsided considerably. The deposition of radioactive materials was extremely uneven so that a person lingering in such a "hot spot" with a gamma reading of 200 roentgen would receive a dose in excess of the daily "tolerance" limit in about 45 seconds.

It is, however, impossible to estimate the full extent of over-exposure for individuals from the documents that we have. The "attitude of indifference" of many officers to safety meant that it was common to find men aboard a "ship in large quantities without film badges or monitors. These men were in superstructures where readings of five roentgen [per day], were common." Such readings meant that a week of four-hour shifts might produce a whole body gamma dose in excess of 5 roentgens. Where film badges were worn, many cases of overexposure were recorded on specific days, even with respect to experienced radiation monitors.²⁰

D. Beta Radiation

"Contamination of hands and faces with beta emitters of intensities greater than tolerance (0.8R/day) is exceedingly common. It is not infrequent to find personnel with bare hands bordering on erythema dose levels if not removed within 24 hours..."²¹

Col. S. L. Warren
Chief, Radiological Safety Section

The average value of beta radiation found was ten times greater than gamma; though in setting the standards, the Medico-Legal Board had assumed this ratio would be only five-to-one. Consequently personnel receiving

"tolerance" doses of gamma radiation were receiving, on the average, twice the "tolerance" dose of beta radiation. Moreover, much higher ratios of beta to gamma radiation were also common. It is probably for this reason that Col. Warren found overexposure to beta radiation "exceedingly common." It is to be emphasized that doses "bordering on erythema"* are equivalent to 300 rads or more to the skin. Yet, the conditions were such that, according to Col. Warren, it was "almost impossible to enforce the wearing of gloves continuously on badly contaminated ships....Nor is it feasible to expect them to take care of their contaminated clothes."²³

The inhalation hazard for fission products from "fine dry particles, spray and fine water droplets" was so serious and insidious that even ordinary masks did nothing but provide a "false sense of security."²⁴ Only a special U.S. Navy "Breathing Apparatus" would be effective and it appears that such was not in general use for several weeks after Test Baker, if ever. We were not able to determine from the documents whether or not such apparatus was available for the decontamination work and not used.

Even changing contaminated work clothes was a hazard since it loosened radioactive particles and created a greater inhalation danger -- and possibly substantial internal doses.

E. Alpha Radiation

"Every contaminated place as evidenced by the gamma or beta radiation on any surface of any vessel may be in fact the residence of many lethal doses of this alpha emitter [plutonium]. This alpha emitter is the most poisonous chemical known. It can only

*Erythema is inflammation or reddening of the skin.

be measured with very precise equipment which is not available and cannot be made available."²⁵

Col. S. L. Warren
Chief, Radiological Safety Section

Plutonium, an alpha emitter and the basic ingredient of the atom bombs exploded at Operation Crossroads, was mixed in with the fission products and distributed throughout the test site in the same way as the fission products. Col. Warren noted on August 7, 1946, that "some of the most important ships have many lethal doses deposited on them and retained in crevices and other places." A few days later he concluded that "no one can say any place is safe for any given length of time" because of the unpredictable presence of alpha emitters and a lack of protective and measuring equipment.*

Still for weeks after the test, men boarded the target ships, hosed, scrubbed, swept and scraped them and prepared the ships for towing. The men even slept aboard them. They were thus constantly exposed to the danger of inhaling fine spray or particles which contained plutonium and/or fission products and neutron induced radionuclides. It is of particular relevance to note that recent research has revealed that "plutonium is concentrated on the sea surface and in sea spray."²⁸ The men were thus subject to a

*Karl Morgan's report²⁷ shows no alpha emitters in the few air samples tested for them with filtration equipment. This equipment worked erratically under the conditions of high temperature and humidity at Bikini. So its use was strictly limited. Moreover, the measurements were only made on a few non-target ships (date of measurement is uncertain) and did not apply to the conditions of resuspension of alpha emitters lodged in rust, paint, wood, etc. as the men worked. Chemical analysis showed extensive plutonium contamination of the ships. In one case, this applied to a sample which had been declared free of alpha emitters by an on-the-spot check.

greater hazard from plutonium inhalation than previously believed. Just by being there and breathing the spray from the waves it was possible to inhale dangerous quantities of plutonium -- to say nothing of the activities that further stirred it up and increased its presence in the air as the men worked. In was, indeed, as Col. Warren came to conclude a few months later, an "insidious hazard" that pervaded the entire area.²⁹

F. Some Legal Aspects

"Col. Fields said that Gen. Groves [the director of the Manhattan Project which made the first atomic bombs] is very much afraid of claims being instituted by men who participated in the Bikini tests."³⁰

Decontamination Report

There is some evidence that many of the assurances regarding safety were made with an eye to answering future claims of radiation injury. The Medico-Legal Board declared that its initial purpose was to "reassure Col. Warren that the safety measures adopted by RadSafe were such as to attract no justifiable criticism, and to give what assurance was possible that no successful suits could be brought on account of the radiological hazards of Operation Crossroads."³¹

Given the extensive contamination, the lack of training of the personnel, the ignorance about decontamination procedures, the lack of adequate instruments, etc., the Radiological Safety Section clearly worked under some apprehension and considerable strain. When their contracts were up in mid-August, "attempts to delay these men were met with unanimous refusal."³² Col. Warren was clearly seriously concerned about the overexposures and the serious hazards in which the men were working.

"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."³³

This and similar statements show a reluctance to acknowledge the extent of the damage that had already occurred. Col. Warren's own statements, discussed above, document that the men were overexposed routinely and that they worked on ships which were 90% decontaminated were still very dangerously radioactive. Certainly, the knowledge of the Safety Section itself was much poorer right after Test Baker on July 25, 1946, than it was on August 7, 1946, when Col. Warren acknowledged the presence of widespread alpha contamination which could not be dealt with at all under the circumstances. Col. Warren's concerns about safety are evidenced in the fact that he recommended that the decontamination operations be shut down in a week. But extensive damage had likely already been done to large numbers of men who had been exposed to high levels of radioactivity in the course of their life and work in the weeks after Test Baker.

G. Instruments

"The test turned out to be literally a hundred times larger than the original conception....We had to make decisions on instruments...at a time when the manufacturing program was non-existent... and we had to make essentially what could be made."³⁴

Col. S. L. Warren
Chief, Radiological Safety Section

"The 'experimental nature' of the instruments might be criticized as implying 'not proven' or known and hence possibly unsafe."³⁵

Capt. George M. Lyon
Safety Advisor, Radiological Safety
Section

The radiological danger to the personnel because of the nature of the tests, the haste with which it was conducted, and "the attitude of indifference" on the part of many officers was compounded by unsatisfactory and untested instruments. For some crucial radioactivity measurements, instruments were not available at all.

The X-263 was, for instance, one of the basic instruments at the disposal of the monitors. Little more than a month prior to the first test, Donald Collins discovered that only 1% of the crucial counter tubes in the second shipment were acceptable, compared to 90% in the first.

The instrument had not been field tested and performed poorly. Dr. William Myers who had been an enthusiastic participant in Operation Crossroads noted that the X-263 "too often failed to function entirely." When working, it "became very erratic and was often misleading on the 20X scale when it was essential that it function well." Finally, it "did not measure high enough radiation intensities."³⁶ The documents repeatedly record questions regarding the reliability of this instrument to accurately locate contaminated areas.

Even when it did work, it could only measure gamma radiation reliably. It did not measure alpha radiation at all. Its measurements of beta radiation were often unreliable.

The instrument thus provided some sketchy data about gamma radiation and much less about beta radiation. There were no field instruments at all to measure alpha radiation from substances such as plutonium. Karl Morgan and his team from Oak Ridge measured some air samples with filtration equipment to check for alpha radiation. However, this equipment did not work properly under the high temperature and humidity conditions at Bikini. It was therefore not used as a field instrument.³⁷

Finally, almost all radiation measurements in the field related to external doses. There was no systematic measurement at Bikini for internal doses which personnel might get and continue getting for the rest of their lives by the inhalation, ingestion or absorption of fission products or alpha emitters like plutonium at Operation Crossroads.

Thus, every aspect of Operation Crossroads, especially after July 25, 1946, was fraught with danger for the 42,000 people present. The documents show that because of the indifference to safety, the lack of caution in spite of grave ignorance, and other factors, it is probable that large numbers of personnel were exposed to very high levels of radiation, particularly internal doses from fission products and plutonium, which continue to irradiate long after the Operation was declared closed and the target ships sunk.

References to Chapter III

1. Stafford L. Warren, Memorandum to Commander Task Group 1.2, USS Haven, 13 August 1946.
2. R. J. Buettner, "Safety Prediction - Test Baker," undated.
3. Director of Ship Material. Radiological Decontamination of Target and Non-Target Vessels, 3 vols., U.S. Navy, undated; vol. 1, p. 4.
4. U.S. Navy, Report on Atomic Bomb Tests Able and Baker (Operation Crossroads). Washington, D.C., 15 November 1946; p. VII(C)(6).
5. cf. supra, #3; vol. 1, p. 25.
6. Preliminary Report of Nuclear Radiation Effects in Tests Able and Baker, From "013E" to "013," 25 September 1946; Appendix VII, Section E.
7. cf. supra, #4; p. VI(D)(41)
8. Ibid., p. VI(D)(21)
9. cf. supra, #2; p. 17.
10. cf. supra, #4; p. VI(D)(45)
11. cf. supra, #3; vol. 1, p. 18.
12. Ibid., vol. 1, p. 25.
13. cf. supra, #1.
14. Karl Z. Morgan, "Final Report on the Alpha, Beta, Gamma Survey Sec.," 6 August 1946.
15. Radiological Safety Monitors for Prinz Eugen, memorandum to Lt. Comdr. Wulfmann, "Subject: Radiological Conditions aboard the USS Prinz Eugen," USS Haven, 10 August 1946.
16. George M. Lyon, Memorandum to Admiral Parsons, Subject: "Ensign Coffin," 5 May 1947.
17. Medico-Legal Board, Minutes of 10 August 1946 meeting.
18. cf. supra, #4; p. VI(D)(44).
19. cf. supra, #6; Appendix VII, Section E.
20. cf. supra, #17.
21. Stafford L. Warren, Memorandum to the Commander Joint Task Force One, Subject: "Occupancy of Target Vessels as Influenced by Intensity of Radiation of Various Types on Target Vessels," 7 August 1946.

References to Chapter III - continued

22. cf. supra, #6; Appendix VII.
23. cf. supra, #7.
24. Ibid.
25. cf. supra, #1.
26. cf. supra, #21.
27. cf. supra, #14.
28. J.A. Garland and R.C. Chadwick, "Plutonium Suspension from Seawater," Health Physics, vol. 41, August, 1981, pp. 279-83.
29. Stafford L. Warren, Memorandum to Major Gen. L.R. Groves, Subject: "Clearance of 'Discussion on product contamination after underwater bomb detonation' during part of informal talks on safety at Bikini," 9 October 1946.
30. cf. supra, #3, vol. 3, p. 112.
31. Medico-Legal Board, "Appendix XX: Report of the Medico-Legal Board," 15 August 1946.
32. cf. supra, #21.
33. Ibid.
34. Stafford L. Warren, Letter to William G. Myers, 31 December 1946.
35. cf. supra, #16.
36. William G. Myers, Letter to Stafford L. Warren, 28 August 1946.
37. Karl Z. Morgan, personal communication, May 21, 1983.

Chapter IV

Radiation Standards

In view of the experience with this whole subject [of radiation standards] in the past, it is my recommendation that no attempt be made to fix a range of tolerances for military operation....They would hardly be worth the paper they are printed on..."¹

Col. S. L. Warren
Chief, Radiological Safety Section
in January, 1947

An irradiation of the whole body at a rate of one-tenth of a roentgen per day (0.1R) was set as the "tolerance" dose above which a person would be considered "over-exposed for that day."* This limit was set in 1934² and was "the tolerance limit set up by the United States Bureau of Standards ...for manufacturing plants in the U.S."³ It was based on a study of three technicians who were exposed to gamma radiation from radium at levels of exposure that did not produce immediately observable damage, mainly reddening of the skin. This "threshold" concept was similarly defined as the dose of radiation measured by the length of time it took for a given radiation flux to produce reddening of the skin.

Later the first dose limit for internal exposures was set in 1941 at 0.1 microcurie "Maximum Body Burden" of radium-226.⁴ After the agonizing deaths of several radium dial painters in the United States, it was assumed that one ten-millionth of a curie of this internal alpha emitter was extremely dangerous. In other words, by 1946 and until 1949, the internal and external dose limits were mainly designed to protect people from tissue

*The annual limit was 30 roentgen.

damage like erythema, anemia and acute forms of radiation damage and did not protect against chronic forms of damage such as carcinogenesis.

At the outset, it might have seemed eminently reasonable to apply the "tolerance" limit for industries to atomic explosions. But as the days wore on, after the disastrous contamination which resulted from Test Baker, it became more and more clear that a gross mistake had been made, even if one granted the unwarranted presumption of adequacy to the industrial "tolerance" limits which were subsequently considerably reduced by the National Commission on Radiation Protection to 0.3 rem per week in 1949 and to 5 rem per year in 1957.

In industries, the locations and intensities of the primary sources of radiation are better known and fixed. Well-calibrated instruments can be used to better chart the radioactivity at various locations. Laboratories are available for analysis on site. Thus the wearing of film badges by personnel can be expected to give a fair indication of external whole body radiation once the film badges are developed and read. Even this is no assurance of adequate safety. For instance, the problem of internal intake of radioactive materials must still be addressed.

Conditions after an atomic explosion, particularly one such as Test Baker which contaminated and set in motion a vast quantity of radioactive water and spray, are entirely different. The location of the radioactive materials is unknown. There were no remote measuring instruments, so that monitors had to go into highly radioactive areas in order to get an indication of how radioactive the general area was.

Even once an area had been declared approachable for a certain time interval, using measurements from experimental and often faulty instruments,

there was an immense and unpredictable variability in the radiation. The maximum radiation was, on some target ships such as Salt Lake City, fifty times the average and radiation levels could vary by a factor of one hundred within a short distance.⁵

Besides these differences in conditions, there was the widespread presence of beta and alpha radiation on the ships.

The Medico-Legal committee, recognizing this and the fact that beta radiation levels were often several times the gamma, adopted the following exposure standard one week after Test Baker:

"The permissible dose of irradiation to the entire body will not be exceeded if the gamma irradiation is held below 0.1R per 24 hours. (This is on the basis of limit of 0.5R of beta per 24 hours)."⁶

Thus the permissible dose for external beta irradiation, which can seriously affect the skin, hands and all exposed parts of the body as well as certain soft tissues near the surface like lenses of the eyes, was set at five times the gamma level. Even this was on the presumption that beta radiation on the average was only five times the gamma. (The routine film badges which were issued to personnel measured only gamma radiation.) In practice the ratio of beta to gamma radiation was extremely variable and could reach one hundred or more. Karl Morgan measured one beta radiation level six hundred times the gamma.⁷ Thus a standard for beta radiation based on gamma radiation measurements was inherently defective. It was in this regard that Col. Warren noted:

"Practices which can be applied with safety in industrial plants through long time supervised training and guidance cannot be employed with safety in the attack on the present problem...."⁸

If the situation regarding external radiation standards was highly unsatisfactory, internal irradiation, including alpha emitters, was much worse. In fact, the documents we have examined indicate there were no formal standards for alpha emitters at all, and no operable field instruments to measure alpha radiation. Tolerances, based on the Manhattan Project, were discussed, and the doses implicit in these were very high indeed.

In a memo to Col. Warren, R. R. Coveyou (one of seven surveyors brought in by Karl Morgan from Oak Ridge National Lab), presented sample calculations showing how much plutonium sailors would inhale if the surfaces being worked on were contaminated up to a suggested tolerance level.⁹ Using current methods of calculation, we estimate that one of the highest cases cited would amount to a one to nine rem to the bone surface per four hours working shift.^{*10} Thus for a twenty-day working month, the dose would be enormous: 20 to 180 rem. A few days prior to Test Baker, the Medico-Legal Board had raised the "question as to the actual danger to CROSSROADS personnel from plutonium dispersed by the Baker nuclear explosion...."¹¹ but thought the problem manageable and the plan of the Radiological Safety Section to be "adequate" even in the worst situation.

In actual practice, the Radiological Safety Section had no plan to deal with plutonium or other alpha emitters as such. It had presumed that gamma radiation measurements would be adequate to the job and paid no specific attention, as far as can be discerned from the documents, to "the most poisonous chemical known."

Two weeks after Test Baker, it had become evident that alpha radiation was a serious hazard which was "extensive and unpredictable," the more so as no field instruments were available to measure it.

^{*}This would be the total internal dose to the bone surface, over a lifetime, resulting from a four-hour shift.

The problem of measuring the extent of a ship's alpha contamination turned out to be insurmountable even after samples of materials from contaminated ships were sent to laboratories. Dr. Herbert Scoville commented on the measurements obtained from samples from a non-target ship:

"The total [alpha] contamination on the ship is estimated to be about 2000 micrograms, but this value may be in considerable error due to different degrees of contamination in various locations and the difficulty of averaging the various readings in order to obtain the total contamination on the ship...."¹²

Since there was no satisfactory way to address the problem of alpha measurements and standards directly for unpredictably contaminated ships, the problem of standards for exposure became a much more difficult one.

According to the Decontamination Report:

"....The revelation of the presence of alpha emitters with the fission products, the lack of instruments for detecting alpha emitters and the absence of standards for safe exposure to them, had introduced an indeterminate factor in all deliberations as to radiological safety. Consequently.... 0.01R/day... was selected as the arbitrary external radiation intensity below which all salt water systems should be reduced for clearance of active ships."⁸

Thus, the military decided on an "arbitrary external radiation intensity" ten times lower than the previous standard of 0.1R/day in part to compensate for an inherently unpredictable distribution of plutonium and in part to account for the much more rapid decay of gamma radiation sources compared to alpha emitters.

Precisely because it was an arbitrary standard, the military found that "no radiologists of recognized authority were ready to declare the figure safe until a study had been made of all the factors involved."¹³

The situation proved so intractable and dangerous that the standard was once again lowered tenfold:

"...it was ruled that final clearance maximum allowable readings for all ships would be .001R/day gamma for shielded readings and .005R/day combined gamma and beta for exposed surfaces pending further developments."¹⁴

Even so, there was no assurance that someone would not ingest a deadly amount of plutonium.

References to Chapter IV

1. Stafford L. Warren, Memorandum to Admiral W.S. Parsons, Subject: "Wartime Radiation Tolerances," 18 January 1947.
2. Radium Protection for Amounts up to 300 Milligrams, U.S. Bureau of Standards Handbook #18, 17 March 1934.
3. Stafford L. Warren, Summary of Lecture on Safety to Monitors, 31 May 1946.
4. Safe Handling of Radioactive Luminous Compounds, Handbook of the National Bureau of Standards H-27, May 2, 1941.
5. Preliminary Report of Nuclear Radiation Effects in Tests Able and Baker, from "O13E" to "O13," 25 September 1946; Appendix VII.
6. Medico-Legal Board, Minutes of meetings on 2-3 August; 3 August 1946.
7. Karl Z. Morgan, personal communication, May 21, 1983.
8. Stafford L. Warren, Memorandum to Commander Joint Task Force One, Subject: "Occupancy of Target Vessels as Influenced by the Intensity of Radiation of Various Types of Target Vessels," 7 August 1946.
9. R.R. Coveyou, Memorandum to S.L. Warren, Subject: "Gamma-Alpha Equivalence for Flat Surfaces," 26 August 1946.
10. K.F. Eckerman, et al., "Internal Dosimetry Data and Methods -- Part 2, vol. 1: Committed Dose Equivalent and Secondary Limits," NUREG/CR-1962, vol. 1, February 1981.
11. Medico-Legal Board, "Report of the Medico-Legal Board on Plutonium Hazard Associated with Test Baker," 22 July 1946.
12. Herbert Scoville, Letter to Captain G.M. Lyon, Subject: "Comments on Results of the Investigations on the USS ROCKBRIDGE," 21 November 1946.
13. Director of Ship Material. Radiological Decontamination of Target and Non-Target Vessels, 3 vols., U.S. Navy, undated; vol. 1, p. 41.
14. Ibid.

Chapter V

Operation CROSSROADS and the Defense Nuclear Agency

"The potential for such [alpha] exposure at CROSSROADS was very low."¹

Defense Nuclear Agency

"Compared to other tests, exposures for CROSSROADS are relatively low."²

U.S. Navy

In numerous Veterans Administration cases brought by CROSSROADS veterans, the Defense Nuclear Agency has maintained that radiation doses, both internal and external, were low. In its dose assessments, the Agency assumes that the radiological guidelines were obeyed, that the standards were adequate, and that the radiation monitoring equipment worked well. Using these assumptions, the Defense Nuclear Agency arrives at its conclusion that the doses were low for specific veterans, without systematically taking into account what that particular veteran did during and after the test.

The official records of Operation CROSSROADS show that the Defense Nuclear Agency's assumptions are without foundation in fact -- which renders its conclusions about doses unscientific. The Joint Task Force had not made any plans for decontamination. Nor did anyone know how to decontaminate a ship. The radiation standards were several times today's levels for external gamma and beta radiation. There were no official standards for alpha radiation or internal doses, so far as can be determined. Many of the instruments did not work well -- and most of them were

experimental ones made in great haste. There were no field instruments at all for alpha radiation -- and eventually it turned out to be impossible to estimate the actual extent of the alpha contamination of the ships. All that could be determined was that it was "extensive and unpredictable."

The Defense Nuclear Agency has dismissed the internal dose as "essentially insignificant."³ Yet Col. Warren, as noted above, the Chief of the Radiological Safety Section of Operation CROSSROADS, stated that "no one can say any place is safe for any length of time" because "any surface of any vessel may be in fact the residence of many lethal doses of this alpha emitter." Since the men were sweeping, scrubbing, hosing down and even sleeping on heavily contaminated ships, the Defense Nuclear Agency's outright claim must be dismissed as baseless. Indeed, the circumstances make it likely that a great many men absorbed significant amounts of alpha emitters which continue to irradiate the portions of their bodies where they are incorporated.

These comments about alpha emitters also apply to internal doses from fission products. In addition, the Radiological Safety Section found that external overexposures to hands were "exceedingly common" and that very high doses bordering on erythema were "not infrequent."

In its calculations of beta radiation dose, the Defense Nuclear Agency has further claimed that the beta and gamma radiation levels were approximately equal.⁴ In contrast, the documents show that beta radiation levels averaged ten times the gamma levels and reached up to one hundred times in certain areas.⁵

The presence of radiological "hot spots," many of which were unknown, make it likely that many men received high doses merely by lingering in such areas. In general, the unpredictable and ill-defined nature of the

contamination make it essential that a detailed knowledge of each specific veteran's activities be used as basic data in estimating possible doses. Even so, the lack of adequate and systematic knowledge of the radiological conditions make it unlikely that any definitive statements can be made about specific persons who were present at Operation CROSSROADS for any length of time.

The "hairy-chested" "attitude of indifference" to radiological matters contributed largely to the dangers to which the personnel were subjected. Such attitudes contributed to extensive violations of radiological guidelines (not wearing protective clothing like gloves, for instance) -- in direct contrast to the assumptions of the Defense Nuclear Agency.

The information in the documents does not allow us to make even rough estimates of exposures. But it does allow us to dismiss as unwarranted any sweeping claims that the doses were "low" or "essentially insignificant" -- particularly as the Defense Nuclear Agency has made such claims without systematic reference to the veterans' detailed accounts of their own activities -- data we consider essential to any serious judgment on the matter.

References to Chapter V

1. U.S. Navy, "History of New York at Crossroads," undated.
2. Enclosure to letter by Capt. W.H. Loeffler, U.S. Navy to Veterans Administration, entitled: "History of USS Salt Lake City (CA-25) During Operation Crossroads (1946)," 17 August 1982.
3. Defense Nuclear Agency, "Fact Sheet, Subject: Nuclear Test Personnel Review (NTPR)," Washington, D.C., 1 March 1982.
4. Capt. W.H. Loeffler, U.S. Navy, Letter to National Veterans Law Center, 14 June 1982.
5. Preliminary Report of Nuclear Radiation Effects in Tests Able and Baker, from "013E" to "013," 25 September 1946; Appendix VII, para. E-7.