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# Radiological Contamination at Air Force Bases with Minor Support Roles for Airborne Operations in Atmospheric Tests Conducted at the Nevada Proving Grounds

**Santino E. Cozza**
**Steven E. Rademacher**

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**Headquarters, Air Force Safety Center**
**Weapons Safety Division**
**9700 Avenue G, Southeast**
**Kirtland Air Force Base, NM  87117-5670**

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**The Air Force Safety Center (AFSEC) provides a detailed analysis of potential aircraft radiological contamination for airborne operations in Atmospheric Tests conducted at the Nevada Proving Grounds (NPG), and the effects of the contamination at Air Force Bases with minor supporting roles. This report provides greater detail on this topic than contained in previous AFSEC documents. This report demonstrates that minor aircraft support missions had significantly lower contamination potential than those that conducted atomic cloud sampling missions. This report provides specific details on aircraft contamination potential for various missions, background information on the objectives of supporting missions and aircraft positions during these missions, and the effect of radioactive decay of radiological contaminates from an atmospheric nuclear test.**

**15. SECURITY TERMS**

George AFB nuclear weapon testing radiation exposure assessment Air Force radioactive contamination aircraft radioactive fallout Nevada Proving Grounds Nevada Test Site Installation Restoration

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## List of Acronyms and Abbreviations

| | |
|---|---|
| AEC | Atomic Energy Commission |
| AEDS | Atomic Energy Detection System |
| AFB | Air Force Base |
| AFRPA | Air Force Real Property Agency |
| AFSEC | Air Force Safety Center |
| AFSWC | Air Force Special Weapons Center |
| BRAC | Base Realignment and Closure |
| CONUS | Continental US |
| DNA | Defense Nuclear Agency |
| DOE | Department of Energy |
| EPA | Environmental Protection Agency |
| IBDA | Independent Bomb Damage Assessment |
| NNSS | National Nuclear Security Site |
| NPG | Nevada Proving Grounds |
| NRC | Nuclear Regulatory Commission |
| NTS | Nevada Test Site |
| SU | Survey Unit |

# Radiological Contamination at Air Force Bases with Minor Support Roles for Airborne Operations in Atmospheric Tests Conducted at the Nevada Proving Grounds

## 1.0 Introduction

The United States conducted 1,054 nuclear tests between July 1945 through September 1992 (DOE 2015). Of these, 210 were atmospheric tests, five were underwater, and 839 were underground. The atmospheric tests were almost equally split between those conducted in the Pacific Ocean (mostly Enewetak and Bikini Atolls, and Christmas Island) and the Nevada Proving Grounds (NPG). The NPG was latter called the Nevada Test Site (NTS) and today is called the National Nuclear Security Site (NNSS). Only the atmospheric tests conducted at the NPG are directly pertinent to this report, with key tests conducted under Operations Ranger (1951), Buster-Jangle (1951), Tumbler-Snapper (1952), Upshot-Knothole (1953), Teapot (1955), Plumbbob (1957), Hardtack II (1958), and Dominic II (1962). Nevertheless, some valuable exposure information from environmental studies conducted at Enewetak Atoll provide technical support.

Atmospheric tests of nuclear devices leave residual radioactive materials in the environment, and are from three primary sources: nuclear fuel not transformed in nuclear reactions during detonation (commonly termed unburned fuel), products from the fission of heavy isotopes (e.g., plutonium and uranium) commonly termed fission products, and materials transformed by neutrons and high-energy $\gamma$-rays produced during detonation. The latter are commonly termed activation products, with materials in the vicinity of the detonation being subject to activation, whether present in the environment: soil, water, test structures (steel and concrete), or materials in the weapon. Dependent on the nature of the atmospheric test, there are varied amounts of these residual radioactive materials and their dispersal to the environment. Among the collective atmospheric tests conducted, some residual contamination was left on-site, with the remainder transported off-site by prevailing winds. Contamination remaining in the atmosphere for extended periods contributed to global fallout. The largest contribution to global fallout was from those tests conducted at high altitudes and high-yield thermonuclear devices where injection of radioactive materials into the stratosphere was common. Debris in troposphere was prone for deposition in the local and regional areas around the location of a test.

Personnel, equipment, and vehicles supporting these tests also had the potential to retain radiological contamination. Though it was standard safety practice for tests conducted at the NPG to decontaminate personnel, equipment, and vehicles leaving the site, the aircraft participating in the tests could harbor contamination on the surface of aircraft or within jet engines, oil coolers, air intakes, etc. Radiological control of the residual contamination on aircraft and aviators would have been implemented by the installation where the aircraft landed. For atmospheric tests conducted at NPG, the most extensive air support provided by the Air Force was conducted by aircraft staged in and out of Indian Spring AFB, NV, an installation adjacent and outside the southern boundary of the NPG. Secondarily, air support was staged from Nellis AFB, NV and Kirtland AFB, NM. Numerous other installations hosted aircraft in support of NPG atmospheric tests, but to a much more limited degree on an individual installation basis. The primary radiological safety concern for contamination was the immediate requirement for adherence to external radiation exposure standards established for personnel supporting the nuclear tests. Due to the relatively rapid radioactive decay of fission and activation products produced in the tests, there were diminished radiation safety concerns on a long-term basis after the completion of tests.

In the early 1990's, in relation to Base Realignment and Closure (BRAC) on some installations, concerns were raised for residual radiological contaminants from the washdown of aircraft supporting NPG atmospheric nuclear weapon tests. Dempsey (1992) and Montgomery (1994) discussed the former Norton AFB, Nellis AFB, and Indian Springs AFB in relation to supporting the atmospheric tests. Defense Nuclear Agency (DNA) in 1992 researched the question of radiological impacts from aircraft washdown operations for response to the question posed to the DoD by Senator Glenn (DNA 1992). This was related to the Environmental Protection Agency (EPA) interests at Norton AFB, as discussed by Dempsey (1992). Later, interest was generated for the former McClellan AFB, CA and Castle AFB, CA in relation to BRAC actions (Rademacher 2017). In contrast to radiological concerns for workers during the immediate period of support to atmospheric tests, BRAC actions focused only on the long-term exposure potential to future uses of the former installations for commercial and/or residential purposes. In the mid-2000s, the Air Force Safety Center (AFSEC) was asked by the Air Force Real Property Agency (AFRPA) to assess the impacts of aircraft washdown operations for Castle AFB.

AFSEC provided the AFRPA a detailed summary of aircraft support for atmospheric tests conducted at the NPG from Castle AFB, as well as from other installations in the continental US (CONUS). The information provided to AFRPA was eventually placed in AFSEC Technical Guidebooks, with the latest edition being Rademacher (2017). AFSEC concluded that almost all aircraft providing airborne debris sampling were staged from Indians Springs AFB, NV, with a small number of missions supported from Nellis AFB and a few other bases. In the case of the latter, the missions were based on the sampling of debris clouds at substantial distance from the NPG, e.g., the central and eastern US. AFSEC concluded that debris sampling missions, especially those accomplished in proximity to the NPG, had the greatest potential for residual contamination among aircraft support missions. This was based on an extensive review of Nuclear Test Personnel Review reports prepared by DNA in the early 1980s. Aircraft that tracked nuclear debris clouds typically had a much lower levels of contamination than those that penetrated debris clouds. Similar to aircraft that support debris cloud sampling, these aircraft were also staged predominantly out of Indian Springs AFB. Other airborne support missions conducted by the AF during NPG atmospheric tests had significantly lower contamination potential. This was due to two primary factors: these aircraft did not penetrate the debris clouds and had limited periods in the vicinity of the areas on the NPG where tests were completed. These conditions were not coincidental, all aircraft missions support during atmospheric tests were carefully planned to control radiation exposures to crew members. Because penetration of debris clouds created the greatest potential for exposure to crewmembers and contamination of aircraft surfaces, these actions were closely controlled. Overall, AFSEC recommended completing a survey of locations on Indian Springs AFB as a scaling and upper-bounding basis for other installations. Current radiological impacts of washdown actions on other bases were expected to be negligible to non-existent at other bases due to the lack of aircraft missions that required penetration of debris clouds and a substantially smaller number of aircraft supported by these bases for the NPG test. A survey conducted by USAFSAM in 2009 and 2010 demonstrated that some evidence of residuals from washdown operations existed at Indian Springs AFB, but to a degree of negligible radiological consequences to personnel using the area at the time of survey. Soil samples confirmed the presence of a long-lived fission product and a component in unburned fuel.

More recently, some veterans and civilian dependents residing at George AFB, CA during the 1970s and 1980s raised concerns of radiological impacts from aircraft operations conducted in the 1950s. Their concerns were based on a variety of health concerns. The purpose of this report is provide a greater level of detail supporting the conclusions of AFSEC Technical Guidebooks. These details are formulated primarily from information provided in historical DNA and AF Special Weapons Center (AFSWC) reports. Most of these reports were available to the public many decades ago. The primary focus of this report is to specify details on aircraft positions during specific tests at the NPG. Additionally, analysis will be provided on the degree of contamination on aircraft monitored at Nellis and Indians Springs AFB which flew through debris clouds. This analysis demonstrates that the aircraft supporting debris sampling had significantly greater contamination potential than aircraft supporting other missions. Lastly, greater detail will be provided on the effect of radioactive decay of radiological contaminants. This last factor is key to exposure potential for individuals on George AFB decades after the completion of atmospheric testing support. This factor is also applicable to similar installations that provided only minor aircraft support to NPG tests. In simple terms, months after the completion of a nuclear test, the levels of radiological contamination on surfaces or in soils are substantially reduced because of rapid radiological decay of fission products that were produced in the detonation. This factor is true for the aircraft washdown areas on Indian Springs AFB, but much more pertinent to the case for bases that provided minor support roles. This is because contamination levels of aircraft supported from theses bases had significantly lower exposure potential than those supported by Indian Springs AFB.

## 2.0 Aircraft Contamination Potential

With a few minor exceptions[1], the only missions that required aircraft to be near the debris cloud during the atmospheric testing were those conducting cloud sampling and cloud tracking. Cloud sampling aircraft received a significantly greater amount of contamination than cloud tracking aircraft. The primary factor related to the differences in contamination levels were the drastically higher contamination levels within the debris cloud than on the fringes of the cloud where tracking aircraft maintained their flight patterns. Additionally, external radiation

[1] A few aircraft were involved in tests on the effects of aircraft systems within debris cloud. These aircraft, however, were staged in and out of Indian Springs AFB, and were assigned to the AFSWC.

exposures crew members were subjected to during presence in the debris cloud were directly related to the concentrations of contamination in the debris clouds. The following paragraphs will provide the reader a description of many aircraft mission types supporting NTS atmospheric tests.

## 2.1 Cloud Sampling Missions

The debris cloud sampling missions included penetrations into debris clouds to collect particulate and gaseous fission samples. The samples were used in order to determine the yield and efficiency of the nuclear devices used during the test, scientific details of significance to the AEC and nuclear weapon design laboratories. The primary aircraft used to collect samples were the F-84G and the B-29. Prior to Operation Ranger in 1951, all debris cloud sampling missions were completed by drone aircraft. For the manned sampling missions, "controller" aircraft played a supporting role by directing "sampler" aircraft. Based on attributes of the atomic cloud, the controller, staffed by a scientific advisor, would vector the sampler to the area of the cloud from which the samples were to be collected. The controller dictated the altitude, location, and duration of the cloud penetration. The duration each sampler aircraft spent in the test area was limited by radiation dose. Aircrew on sampling aircraft were equipped with dosimeters and film badges in order to assess radiation intensities in the area and their accumulated dose. The aircrew also had exposure meters that provided real-time feedback on exposure rates. Once sampling was complete, the controller aircraft would designate a return route back to base. Ground operators managed sample downloading and further logistic transport to scientific laboratories. It was imperative that samples were analyzed as quickly as possible in order to measure short-lived isotopes (Fackler 1980).

Some debris cloud sampling missions were accomplished to exercise the US's Atomic Energy Detection System (AEDS), an intelligence capability for detection and analysis of debris from foreign nuclear tests. In contrast to the debris sampling missions conducted shortly after detonations and within proximity to the NTS, AEDS aircraft collected samples across the east coast and outside the continental US. At great distance from the NTS, debris clouds had significantly lower radiological hazards due to radioactive decay, fallout losses, and cloud dispersion. As summarized in Rademacher (2017), AEDS sampler aircraft exercised during Operation Ranger were based from Barksdale AFB, LA, Robins AFB, GA, Alaska, Japan, Guam, and Saudia Arabia. The exercise of this capability during Operation Ranger is historically significant, as the first Soviet nuclear test was conducted about 16 months prior to this test series.

## 2.2 Cloud Tracking Missions

The cloud tracking missions required aircraft to maintain close proximity to the debris cloud, though these missions did not require any penetration of debris clouds. These missions used four aircraft: a B-25 to track the cloud from the ground to the stem, two B-29 to examine the cloud from the stem to the top, and a B-50 to monitor the top of the cloud (the B-50 was often the controller aircraft in the cloud sampling missions.) The B-series aircraft were used for these missions due to their long-range capability (Fackler 1980).

Each aircraft was instructed to visually follow the trajectory of the cloud until it became transparent. At that point, the aircrew would rely on radiation detection instruments to detect fringe areas of the debris cloud. Visually tracking the cloud afforded the aircrew a straightforward opportunity to avoid penetrating the debris. By the time the cloud dispersed to the point where it no longer was identifiable by visual means, the radioactivity content of the debris clouds also presented a significantly diminished potential for radiological contamination compared to periods shortly after the debris cloud formation. In order to follow the trajectory for long distances (up to 600 miles), the B-29 would measure the leading edge of the cloud. The aircrew would continuously measure the radiation intensities, and change directions as the detection instruments started to increase, purposely avoiding penetrating the cloud. The aircraft would record the intensity readings at their position in order to plot the cloud path and dimensions (Parsons 1955). Cloud tracking missions lasted many hours, in contrast to debris sampling missions, which by scientific necessity and radiation safety principles required short mission durations. Despite the substantially longer flight periods, cloud tracking missions were expected to have significantly lower contamination on aircraft surfaces and external radiation to crew members than aircraft and aircrew involved with debris sampling missions. This is due to the significantly higher contamination levels within the debris cloud compared to the levels of radiation exposure aircrew were limited to on the fringe of the debris cloud.

### 2.3 Comparison of Aircraft Contamination for Cloud Sampling vs Cloud Tracking Missions

Operation Ranger in 1951 was the first test series to use manned cloud sampling aircraft. This practice was implemented because scientific data collected from unmanned missions was deemed inadequate. Due to the radiation safety concerns presented by the addition of manned missions in this test series, a significant effort was invested by the AFSWC to evaluate aircraft decontamination efforts in comparison to natural radioactive decay alone. Operation Ranger involved five detonations. For each test, an extensive set of contamination measurements were collected on debris cloud sampling aircraft. For the fifth tests, aircraft that supported cloud tracking missions were also evaluated for radiological contamination. This comparison provides an important basis of comparison of the contamination potential that existed between these two mission types.

For Operation Ranger, ground-based surveys of aircraft performing cloud tracking and debris sampling were staged from Nellis AFB. Dependent on the aircraft, critical survey locations were standardized to allow comparisons from subsequent survey efforts. The locations selected were those that had a tendency to collect contamination such as leading edges of wings, air intakes, and rough surfaces where screws, latches and other fluids existed (Trexler 1983). Table 2-1 contains a listing of the B-29s that were surveyed at Nellis AFB. For the B-29s, 41 survey points were made for each survey. A complete set of results are in Appendix A. Figures 2-1, 2-2, and 2-3 below provide a comparison of the exposure rates for three locations, which were among locations with highest readings. It is very apparent from all three figures that the aircraft conducting debris sampling missions contained significantly more surface contamination than the cloud tracking missions. Some measurements listed an exposure reading as "background." For these, a conservative estimate of 0.05 mR $h^{-1}$ was used for illustration purposes. The

Table 2-1. B-29 Mission Names for Operation Ranger and Mission Type.

| Aircraft Call Name | Test | Mission Type |
|---|---|---|
| Able-1 | Shot 1 - Able | Cloud Sampling |
| Able-2 | Shot 1 – Able | Cloud Sampling |
| Baker | Shot 2 – Baker | Cloud Sampling |
| Easy-1 | Shot 3 – Easy | Cloud Sampling |
| Easy-2 | Shot 3 – Easy | Cloud Sampling |
| Baker 2 | Shot 4 – Baker-2 | Cloud Sampling |
| Fox-1 | Shot 5 - Fox | Cloud Sampling |
| Fox-2 | Shot 5 – Fox | Cloud Sampling |
| Fox-A | Shot 5 – Fox | Cloud Tracking |
| Fox-B | Shot 5 – Fox | Cloud Tracking |
| Fox-C | Shot 5 - Fox | AEDS |

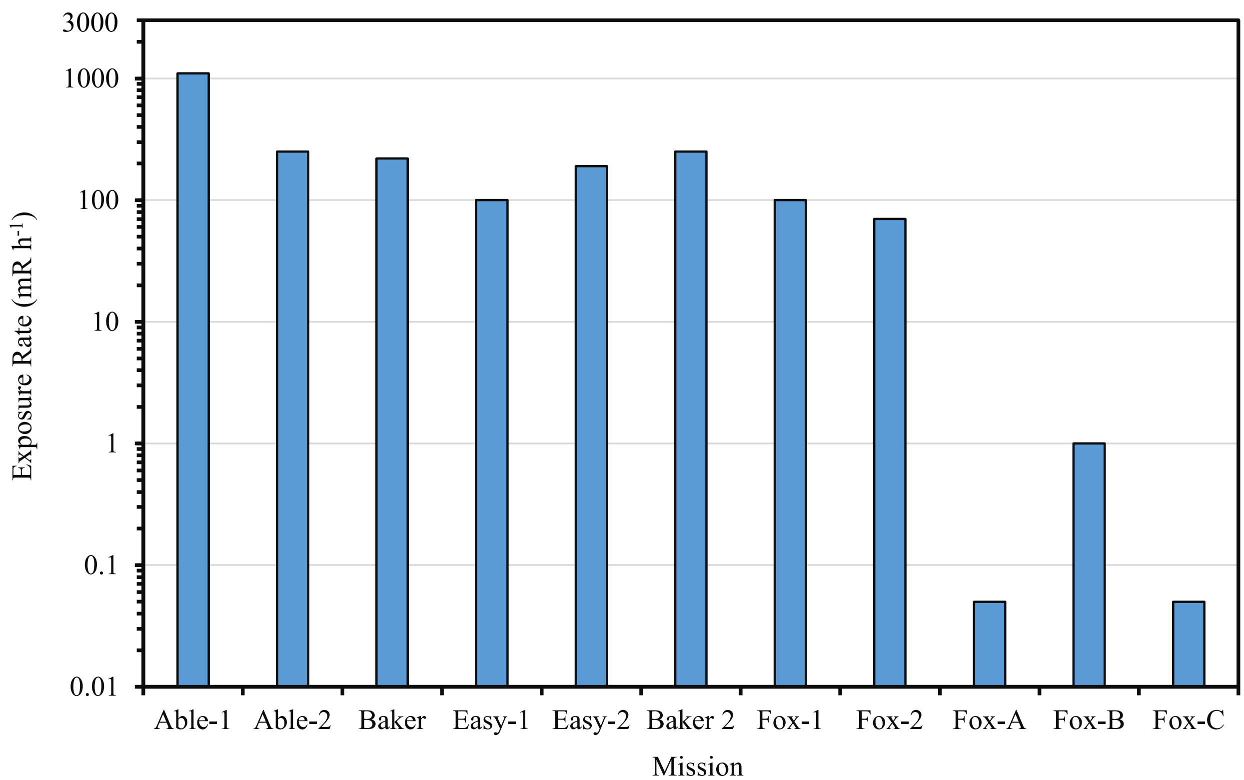


Figure 2-1. Comparison of Exposure Rates From Initial Survey of the Turbo And Exhaust of B-29 Aircraft Used In Sampling and Cloud Tracking Missions. [Data from (Trexler 1983)].

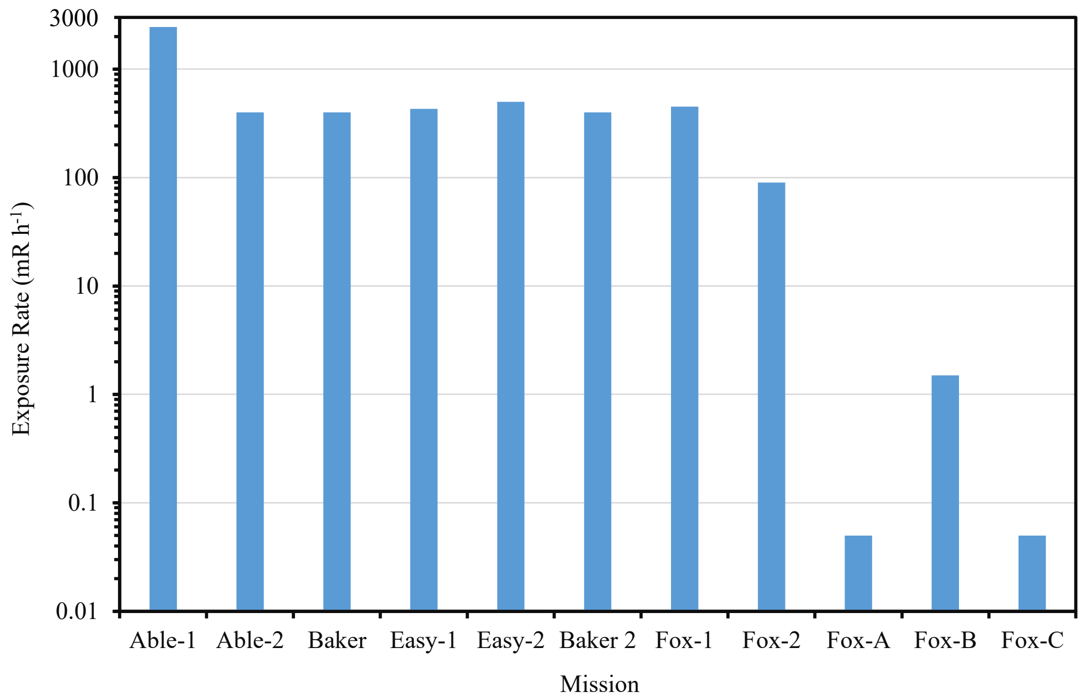


Figure 2-2. Comparison of Exposure Rates From Initial Survey Of The Air Intake of B-29 Aircraft Used In Sampling And Cloud Tracking Missions. [Data from (Trexler 1983)].

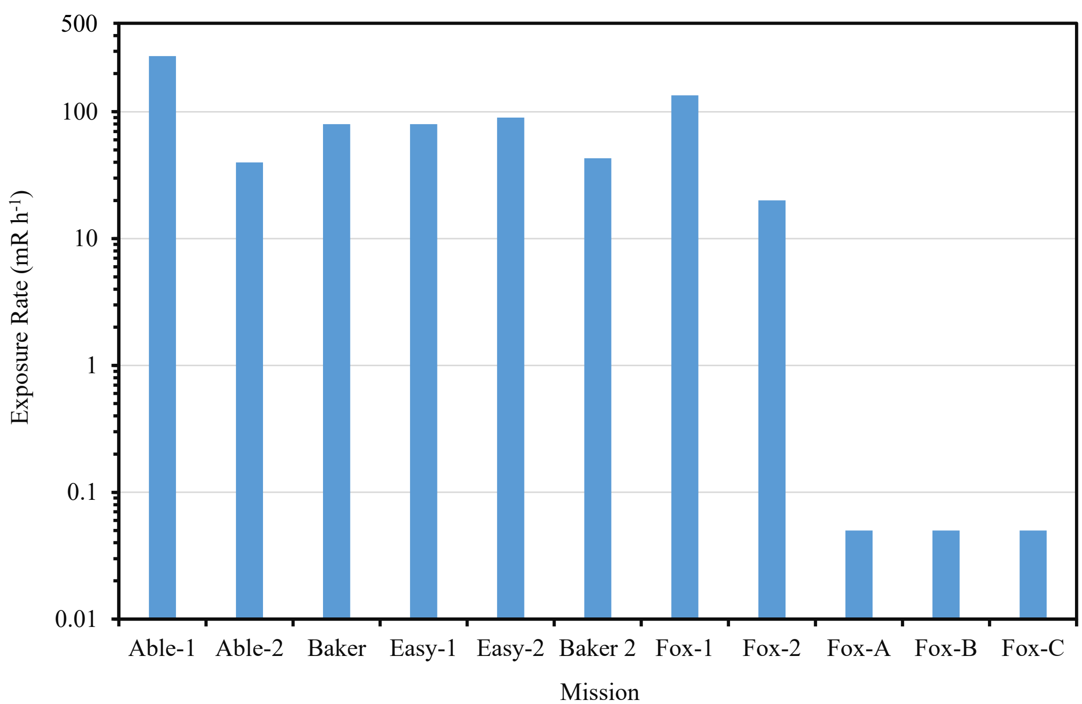


Figure 2-3. Comparison of Exposure Rates From Initial Survey of Leading Edge Wing of B-29 Aircraft Used In Sampling And Cloud Tracking Missions. [Data from (Trexler 1983)]

disparity in the exposure rates in some examples are about three orders of magnitude. Based on similar mission profiles for other tests, e.g., Operation Upshot-Knothole, Operation Teapot, and Operation Plumbbob, similar disparities in exposure rates of aircraft used for debris sampling and cloud tracking are expected.

Though the comparison of initial surveys of exposure on aircraft surfaces provide one basis to appreciate levels of contamination, another source of comparative data is from on-board exposure measurements. Sampling and cloud tracking aircraft were equipped with various instruments to measure radiological intensities (i.e., exposure) during missions (Fackler 1980). The peak radiation intensities during each cloud sampling mission for nuclear tests conducted during Operation Teapot are shown in Figure 2-4. As a basis of comparison, the red line is at 10 mR $h^{-1}$, which was used as the standard exposure rate goal for cloud tracking aircraft (Parsons 1955). Peak exposure rates encountered by aircraft and aircrew on debris sampling missions were well over three to four orders of magnitude higher. This provides an appreciation why sampling aircraft were carefully controlled and had strict time limits in debris clouds. In some cases, multiple passes through the center of the cloud were performed per sampling mission. For the purpose of comparison, radiation exposure rates at ground level from natural background sources in the environment and the vicinity of Indian Springs AFB are about 0.014 mR $h^{-1}$.

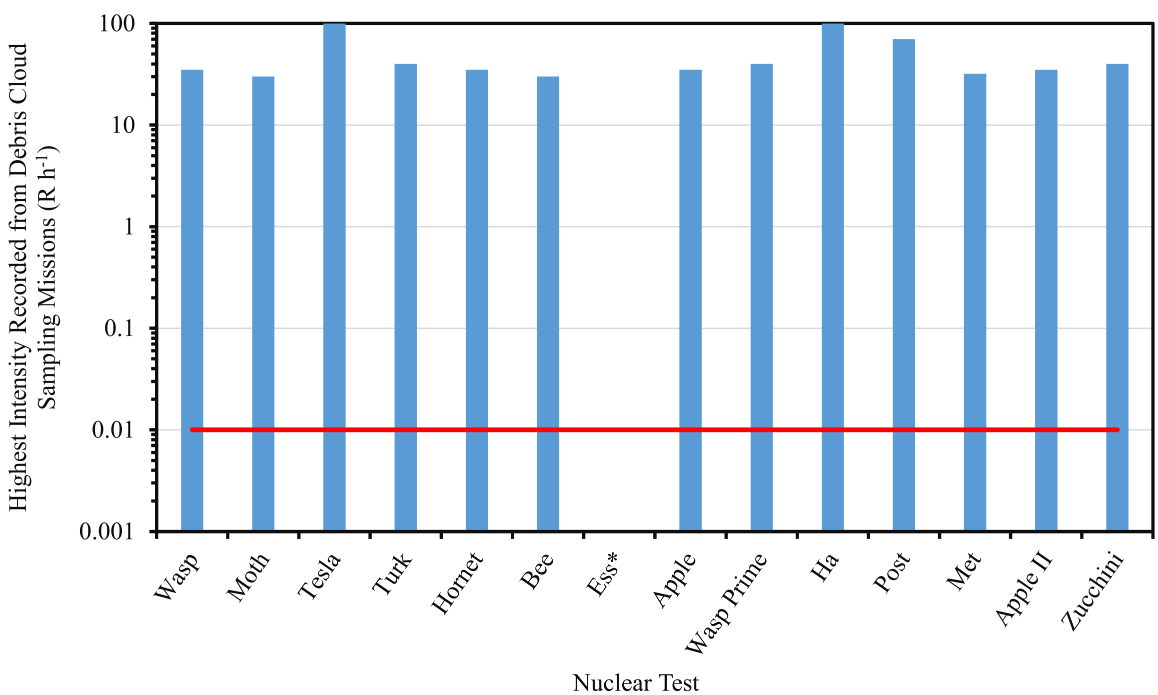


Figure 2-4. Peak Radiation Intensities From Debris Cloud Sampling Missions For Nuclear Test During Operation Teapot. [Data extracted from (Fackler 1980)]. (* Test Ess had a buried device).

To avoid cloud penetration, tracking aircraft would approach the leading edge of the cloud from one side, while measuring the radiation intensity. If the aircraft measured 10 mR $h^{-1}$, it would abruptly turn away, and approach the cloud again from the other side. The frequent turning would continue until the cloud spread to the point where it no longer followed a particular direction (Parsons 1955). As a result, if the tracking aircraft followed the standard procedure, a peak intensity of 10 mR $h^{-1}$ have been the highest recorded exposure rate.

Another point of comparison is the relationship between cumulative exposures received by aircrew in sampling aircraft versus aircrews completing other missions. By far, aircrew performing debris sampling had the greatest recorded exposures among AF aircrews. Aircrew that completed cloud tracking and other missions had much lower external exposure levels. For this reason, external exposures to aircrew completing the debris sampling missions were afforded the greatest degree of radiation safety management during tests. Due to the radiation intensities in the debris cloud, debris sampling missions were often delayed one to two hours after the time of detonation for radiation safety purposes. Similarly, this same radiation safety concern was directed to contamination on aircraft completing debris sampling missions.

Contamination levels on aircraft were also associated with integrated (cumulative) exposure. Figure 2-5 compares the aircraft contamination levels and the integrated exposure for aircrew.

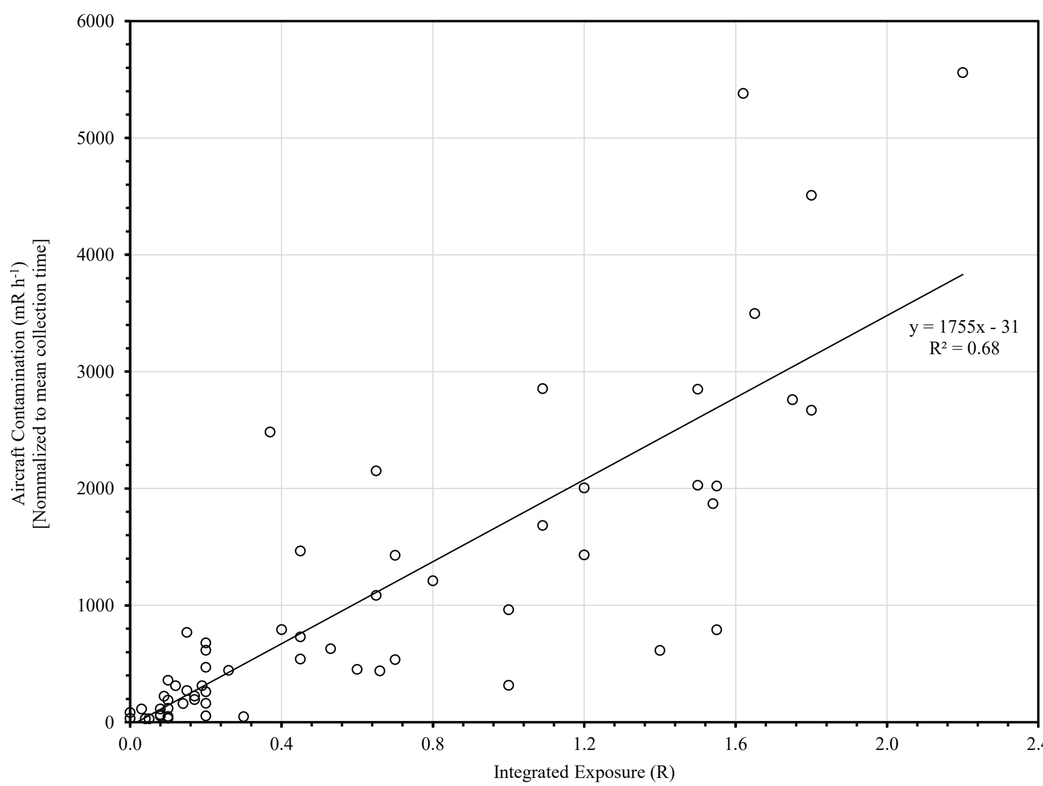


Figure 2-5. Integrated Exposure Vs Aircraft Contamination For Shots Annie through Simon During Operation Upshot-Knothole. [Data extracted from (Fackler 1982)]

The aircraft contamination levels are derived from the initial survey for radiological contamination after the sampling mission was completed. These values were normalized to the mean collection time aircraft were inside of the cloud. The integrated exposure values are from dosimeters the pilots were required to wear during the sampling missions. The regression line in Figure 2-5 illustrates a reasonably good correlation. The data set contained only measurements from shots Annie through Simon for Operation Upshot-Knothole. Comparative data for other tests provided similar results.

## 3.0 Avoiding The Plume

In the previous section, it was indicated that if the aircraft did not penetrated the atomic cloud, there was less of a potential to accumulate residual contamination on the surface. The primary comparison was between debris sampling and cloud tracking aircraft. Radiation safety concerns for other airborne missions were much lower as there was not a necessity to penetrate debris cloud or be within the vicinity of debris clouds for extended periods. With greater distances separating debris clouds and aircraft, the potential for contamination was greatly diminished. As a result, there was an insignificant contamination potential for other missions, and specifically to the types of missions supported from George AFB. For many of these, examination of the purpose of the mission reveals the fact that entering the debris cloud was contrary to mission objective(s). Furthermore, the flight patterns and descriptions of the missions, clearly indicate the distance the aircraft were from the debris cloud.

During atmospherics tests, flight patterns were carefully choreographed to ensure radiation safety and to avoid aviation mishaps. The military and the AEC had strict safety protocols in order to regulate the air space. The aircraft were subject to precise positioning coordinates and timing schedules. There was little tolerance to deviate from the flight plan. If their position was skewed by 200 feet in altitude, 2,500 feet laterally, or their timing was off by anymore than ten seconds, aircrew were directed to abort a mission. Additionally, the aircraft were scheduled to perform sorties before the detonation in order to practice their appropriate flight pattern (Fackler 1980). This was very common for aircraft that performed weapon drops or simulated strike missions. Individual missions are summarized below with a few notable examples. A complete list of aircraft missions executed from George AFB are listed in Appendix B.

### 3.1 Simulated Bomb Delivery Missions

Simulated strike missions were used to train aircrew in atomic bomb delivery techniques. These missions would take advantage of the effects of the detonation to provide the crew a realistic experience of carrying out an offensive strike on a target. The mission required the aircraft to fly in an attack formation over the test site, perform the necessary delivery maneuvers, and turn away from ground zero in order to avoid the shock wave. The aircraft performed their maneuvers miles away from the nuclear cloud, and would only remain in the area for a few minutes after the detonation (Fackler 1982).

During Operation Teapot, shot Tesla, the F-84's participating in simulated bomb delivery missions were recorded performing their maneuvers at the time of detonation 9 kilometers (~5.5 miles or ~29,500 feet) from ground zero at an altitude of 15,000 to 19,000 feet. According to the historical records, these aircraft remained in the area for 10 minutes before returning to base (Maag *et al* 1981a). At these distances from ground zero, the aircraft were only expected to experience less than one calorie of thermal energy, and 0.15 psi from the shock wave (Fackler 1980). For comparison, during other experiments, aircraft that experienced 1 to 2 psi received damage that was repairable, while aircraft that experienced 4 to 10 psi were considered destroyed beyond repair (Glasstone and Dolan 1977).

Figure 3-1 is a plot illustrating debris cloud dimensions at various times post detonation. The vertical green line is positioned at H+10 minutes. The two horizontal red lines represent the range of altitudes aircraft were present performing their maneuvers. As one can infer from these lines, the aircraft were beneath the debris cloud, and had a small likelihood of interacting with any residual radiation that could have contaminated the surface. Furthermore, the gold horizontal line shows the lateral distance the aircraft were from ground zero, and the blue horizontal line demonstrates the cloud diameter 10 minutes after the detonation. The aircraft were ~29,500 feet laterally from the ground zero location, while the cloud diameter was only ~12,100 feet during the period the aircraft were in the area. This positions the F-84's

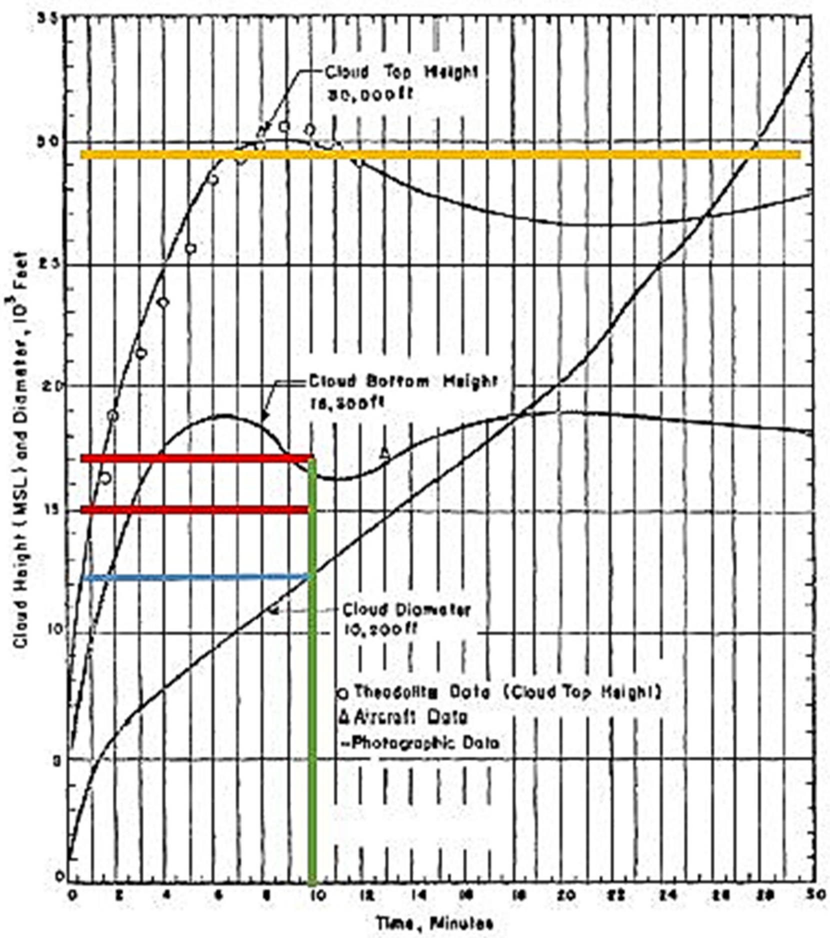


Figure 3-1. Cloud Dimensions With Respect To Time Of Shot Tesla
During Operation Teapot [Data Adapted From (Hawthorne 1979)].

approximately 17,400 feet (3.5 miles) laterally from the debris cloud. It is readily apparent that the potential for radiological contamination to aircraft performing these missions was negligible.

### 3.2 Indirect Bomb Damage Assessment (IBDA) Missions

The purpose of these missions were to determine the reliability and consistency of equipment and techniques used to evaluate the damage generated by the nuclear bomb (Parsons 1955). The supporting aircraft would fly in a pattern away from ground zero, and use the specialized equipment to determine the height of burst, yield, location of ground zero, and other useful characteristics of the shot (Fackler 1982).

### 3.3 Orientation and Indoctrination Missions

This type of training included lectures and briefings on the effects of nuclear weapons, observation of a detonation, and assessment of the damage at ground locations caused by the detonation. The purpose was to teach aircrew about blast, thermal, and radiation effects that may be encountered in a nuclear detonation. The observation portion of the training took place a safe distance from the effects of the detonation (Parsons 1955). The aircraft participating in these tests would fly holding patterns more than fifteen miles from ground zero, and would leave the test area shortly after detonation. For example, during Operation Teapot, shot Ha, aircraft participating in orientation and indoctrination training were charted flying 25 kilometers (~15 miles) SE of air zero for 15 minutes. Once they observed the detonation, they returned to base (Ponton *et al* 1981). Some aircraft supported from George AFB completed these missions.

### 3.4 Photographic Reconnaissance

Photographic reconnaissance was completed to document effects of the detonations for military and civilian purposes, and to assess damage on targets. The aircrew orbited the vicinity of the explosion, and took photographs of ground zero, the debris cloud, and surrounding area (Harris *et al* 1981). These aircraft were required to avoid the debris cloud, as optimal assessment of bomb damage required visual clarity. In most of the flights, the aircraft flew below the debris cloud.

Figure 3-2 is a planned flight pattern for aircraft participating in photo reconnaissance missions at Shot Smoky during Operation Plumbbob. The red arrow in the figure points to the photographic reconnaissance mission flown during the shot. During an interview with a participating pilot staged from George AFB, it was reported that the aircraft orbited the area of Lathrop Wells at 30,000 feet until they received clearance to fly near ground zero to photograph their target. The aircraft were cleared ten minutes after the detonation, and only made one pass of ground zero by flying under the mushroom cloud. They were only in the area for a few minutes before returning back to their home station. According to the pilot, upon returning to George AFB, the aircraft would taxi to a remote area, where they would be monitored for radiological contamination. If there was no contamination, they would taxi to a parking area. If contamination was found, they would remain in the isolated location until the level of contamination reduced to a safe level (Harris *et al* 1981). In a summary report of George AFB's participation in the atmospheric tests to the Commanding General, it was noted, "Training of personnel involved was considered invaluable in spite the fact that no aircraft or person was actually contaminated (Delashaw and Lovell 1953)."  This was a conclusion drawn from George AFB support to Operation Upshot-Knothole, and within expectations, as the aircraft supporting NTS tests from George AFB did not penetrate debris clouds.  Another scientific fact of importance is the distribution of radioactivity in debris clouds that was learned from experience in earlier test series, "90% of the fission debris was usually considered to be in the upper portion of the debris cloud," (Berkhouse et al. 1983).  Hence, though some aircraft had some limited period under debris clouds, the concentrations of radioactive debris within the lower section of the debris clouds had only a small fraction of the fission product inventory.  Figure 3-2 also shows the holding patterns for other aircraft supporting the test.

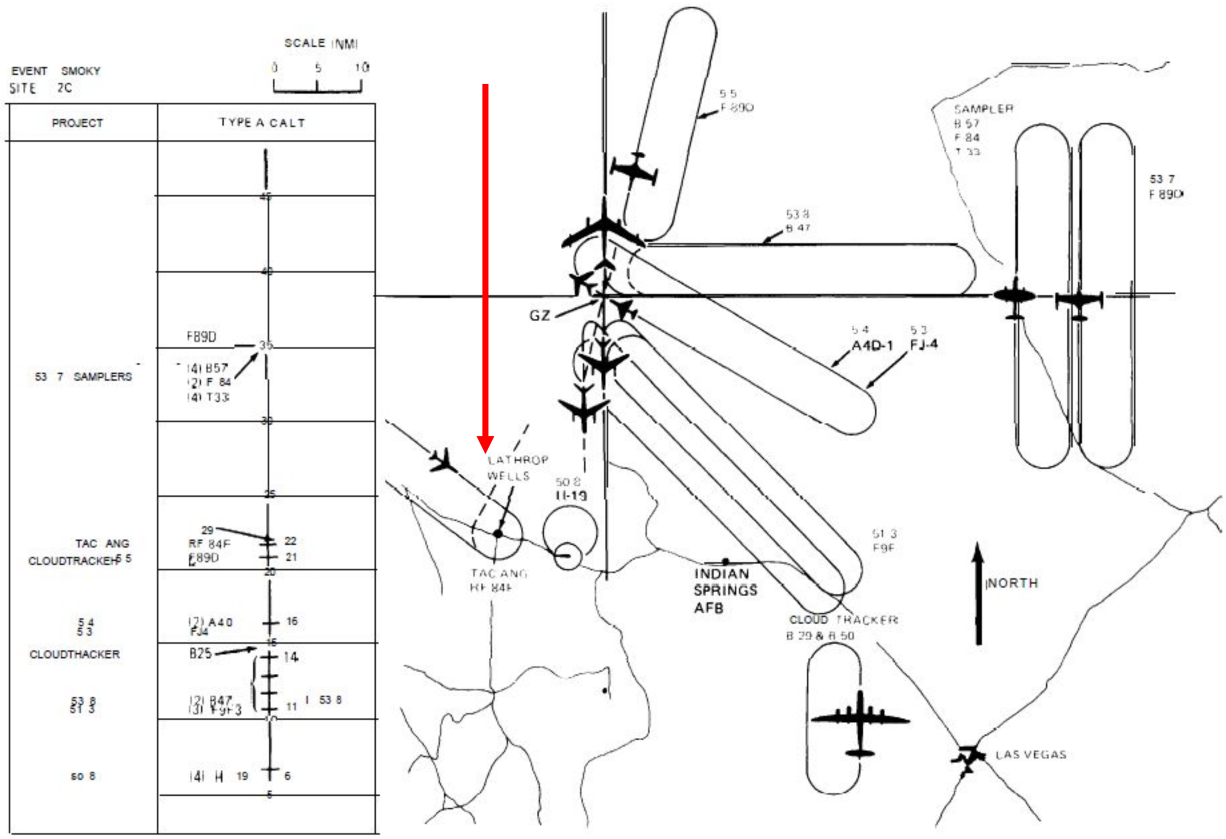


Figure 3-2.  Planned Flight Pattern for Aircraft Participating at Shot Smoky During Operation Plumbbob (Harris *et al* 1981).

### 3.5 Nike Missile Signal Attenuation

The Nike was a surface-to-air missile used for air defense.  The missile would use radar signals to detect and identify targets.  Tests on the operability of these systems during nuclear tests were vital to understand the effects of nuclear radiation on their use in potential future nuclear combat conditions.  Aircraft would support these missions by imitating a target and positioning the debris cloud between themselves and the ground missile site.  A ground team was available to monitor the signal response from the missile signal (Viscuso *et al* 1981). These tests by their design did not require aircraft to penetrate or have close proximity to the debris cloud.

## 4.0 Decay of Radioactive Contamination

The advent of nuclear weapons deployments created a necessity for the military to prepare to manage radiological conditions in armed conflicts. Hence, similar to methods to mitigate possible biological and chemical agent uses in combat, the military prepared suitable methods as applied to radiological contaminants. Decontamination of personnel and equipment had been conducted in support of previous atmospheric tests. George AFB, in support of atmospheric tests for Operation Upshot-Knothole, exercised their capability on potential radiological contaminants, though the methods had some cross-suitability to biological and chemical agents (Delashaw and Lovell 1953). Two key capabilities tests were radiological contamination assessment through the use of portable survey instruments, and aircraft and personnel decontamination.

Overall, during atomic testing, the application of decontamination was based primarily on operational and mission requirements. In some cases, physical isolation of radiological contamination from personnel in conjunction with the rapid radioactive decay of fission and activation products was an effective radiation protection tactic. Some factors that were taken into consideration were the amount of aircraft available, period between each mission, and in some cases the concern of sample integrity. The latter is specific to sampling aircraft. Aircraft were decontaminated during the atmospheric tests primarily used pressurize water spray processes (Trexler 1983). If adequate time between missions, natural decay of the radioactive material was exploited for decontamination purposes (Harris *et al* 1981). This method was useful because it was effective and limited the amount of radiological exposure to personnel. A more detailed analysis of this phenomenon is described later in this report.

To hasten more effective hydraulic decontamination, detergent (trisodium phosphate) and "gunk" (a degreasing agent) were commonly used. The cleaning compounds were applied to the aircraft at high pressure using a spraying apparatus (Trexler 1983). In order to limit the amount of exposure to maintenance personnel, this decontamination process did not involve any physical contact with the aircraft. The runoff of the solution was collected in a drainage trench. The trenches controlled the spread of contamination that may have been released from the aircraft in order to protect workers from inadvertent access. After the aircraft was successfully decontaminated, the drainage trenches were filled with dirt and cordoned to restrict personnel from entering. The area was continuously monitored for radiation exposures until judged safe by radiation safety standards (Delashaw and Lovell 1953).

The source of the contamination originates from the nuclear device. The explosion of the atomic bomb unsettles large quantities of material on the earth (soil, rocks, water, etc), and lifts it into the air. As the material is elevated into the air, it is heated to extreme temperatures (~9000˚F) by the detonation. The temperature is so intense (comparable to the surface of the sun) that all the materials in the near vicinity are vaporized. This includes unburned nuclear fuel that has escaped fission, the weapon casing, fission products, materials in the earth and atmosphere, and all of the substances that comprises the weapon itself. As the temperature begins to cool, all of the vapors condense, and fuse together. When a stable component (earth material, weapon components, etc.) merged with a radioactive component (unburned fuel, fission product, etc.) it became contaminated. This is known as residual radiation. Another source of residual radiation is from interactions with neutrons known as activation. A material with a stable amount of protons and neutrons in the nucleus are bombarded by neutrons and become radioactive or activated. Neutrons can also activate materials that are already radioactive in a process known as transmutation. After a period, the turbulence from the explosion settled, and the contamination would gradually fall to the earth. The contamination had the potential to be spread over large areas from environmental factors such as wind. This is known as fallout (Glasstone 1977).

Once the residual radiation hits the ground, it is classified as fallout. Fallout from a nuclear device can be described in two phases: early and delayed. The early fallout is considered the contamination that reaches the ground in the first 24 hours after the detonation. This type of fallout spreads over a large area near ground zero, and poses an immediate health threat. On the other hand, fallout that stays suspended in the atmosphere for more than a day is known as delayed fallout. The delayed fallout is comprised of small, invisible particulates that travel throughout the atmosphere and gradually fall to the surface of the earth. One important factor in determining the amount of residual radiation and fallout is the height of the detonation. The closer the blast is to the ground, the more potential there is to have dirt lofted into the air. The more dirt there is in the air, the higher the likelihood of contamination (Glasstone and Dolan 1977).

Aircraft supporting the atmospheric tests had the potential to retain radioactive contamination from the debris cloud. This retained contamination is not technically fallout, however, it does have similar characteristics. Among the constituents, fission products are the most important source of external radiation exposure.

Radioactive decay is the process by which an unable atom loses energy by emitting particulate or non-particulate radiation. The decay rates are well known for isotopes of elements and commonly described by the half-life, the expectation time for half the atoms to remain. Eventually unstable atoms undergo nuclear transformation, lose energy in the form of radiation, and become stable. For some, there are multiple radioactive elements in the decay chain. Once stable the atoms no longer present a health threat. Since residual radiation from a nuclear blast consists of over 300 radioactive isotopes, it is impossible to describe the half-life of each one individually. As a result, the decay of residual radiation is approximated by considering the entire group of isotopes (Glasstone and Dolan 1977). The group decay of all fission products has been estimated by the following equation:

$$R(t) = R_0 t^{-1.2},$$

where $R_0$ is the initial radiation intensity, $R(t)$ is the radiation intensity at time, *t*. Figure 4-1, adapted from Glasstone and Dolan (1977), show the dose rate over time post detonation, as normalized to the dose rate at one-hour post detonation. The solid (gray) line is the average for a fission product mixture expected, and the dashed (black) line represents the above equation. As shown in the graphs, the equation fits reasonably well for time up to six months post detonation. After one day, the external dose rates from fission products drops to less than 3% of that at one hour, while at one month, over 3,000-fold lower (Rademacher 2019).

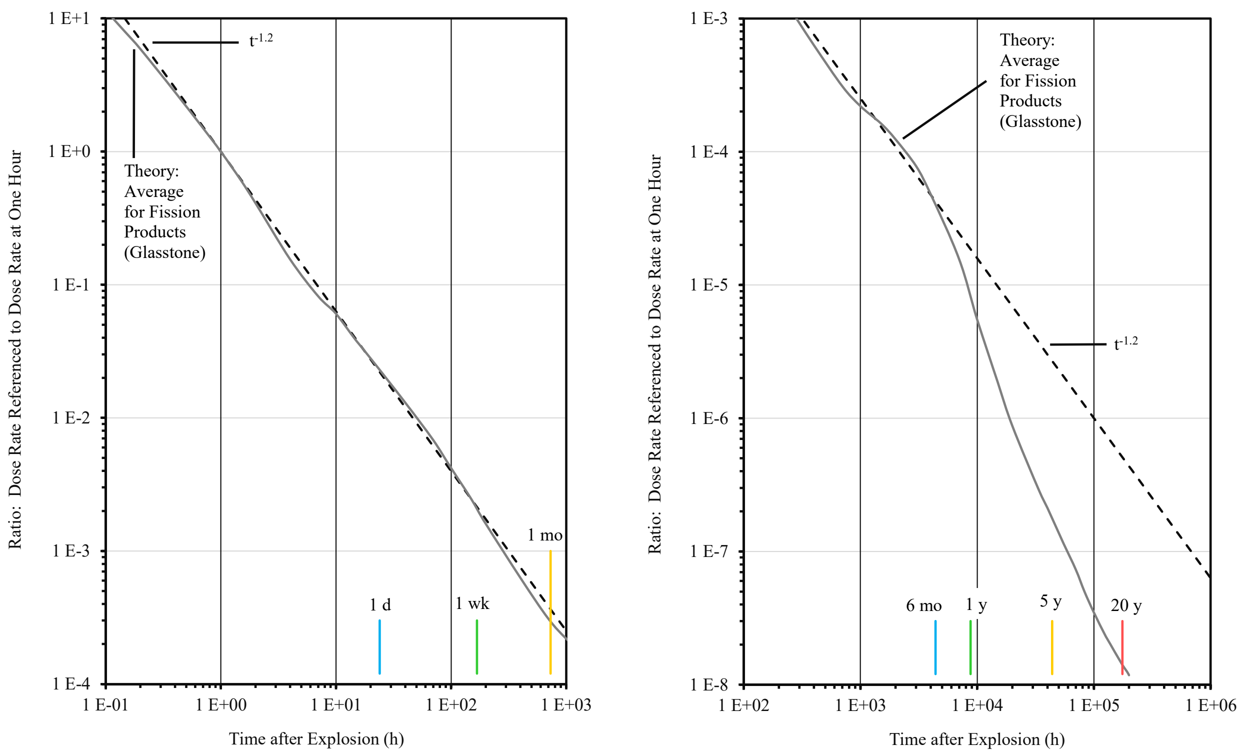


Figure 4-1. External Dose Rate at Various Times After Detonation of Fission Products Reference to One-Hour After Detonation (Glasstone and Dolan 1977).

Most of the isotopes have relatively short radioactive half-lives. As a result, there is a drastic reduction in external exposure rates over short periods after detonation. Early periods after a detonation were important to radiation safety actions for support personnel during tests. In conjunction with tests, the DoD conducted a significant amount of effort evaluating the effects of the natural decay in radioactivity contamination on aircraft, as well as decontamination measures, to reduce support personnel radiation exposures (Rademacher 2017).

To demonstrate the effect of radioactive decay alone, survey data that was collected during Operation Upshot-Knothole was compiled. Upon return to Indian Spring AFB initial survey measurements were collected at a number of standard measurement points on aircraft that completed debris cloud sampling missions. A second set of survey measurements were collected a full day after the initial survey. For the measurements shown here, no decontamination was accomplished between the measurements. While a complete set of measurement are contained in

Appendix C, Figure 4-2 below shows the distribution of decay coefficients, $x$, for paired survey measurements, from the following general equation:

$$R(t) = R_0 t^{-x}.$$

The distribution of decay coefficients demonstrates a good central tendency in the data around -1.15. This value closely follows the theoretical expectation of -1.2, as illustrated in Figure 4-2 for short periods after fission product production. Some of the variability in the distribution is likely due to contributions from activation products (which are not fission products), some variation in survey measurement technique by personnel, and variability between survey times.

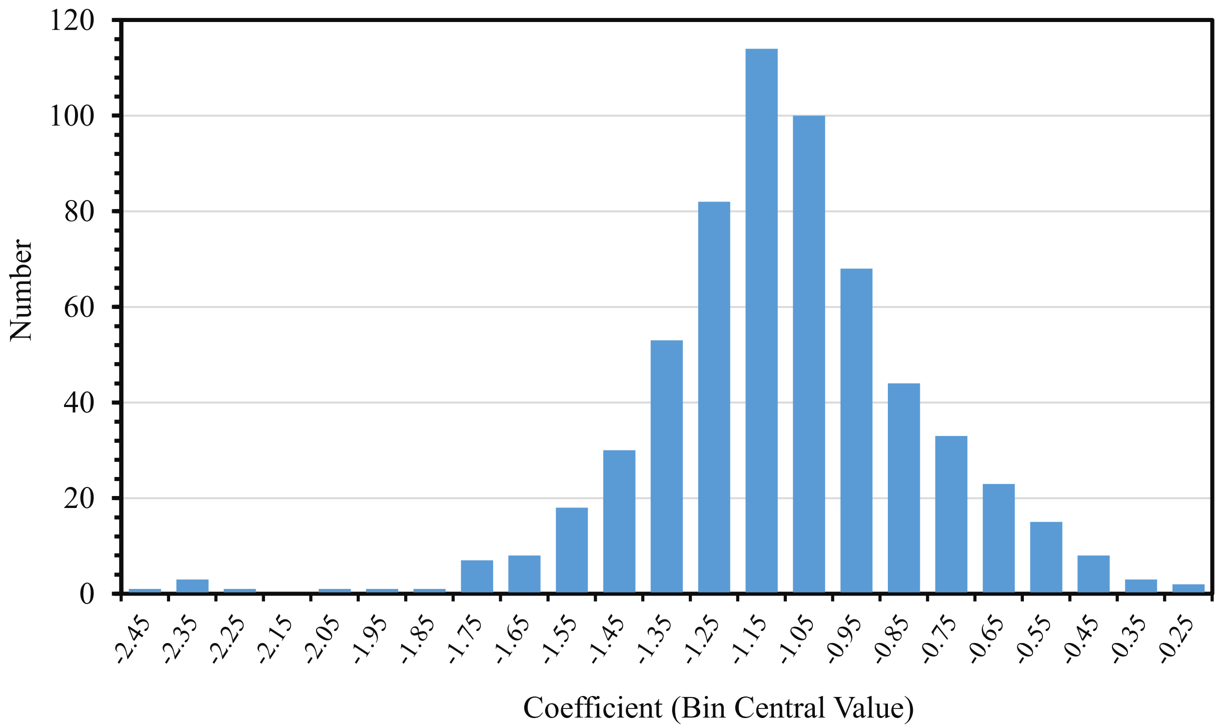


Figure 4-2. Distribution of Coefficient, $x$, Among Exposure Measurements Collected on Aircraft Surfaces for Shots Nancy and Ray, Initial and One-Day Delayed.

While the data above is valuable at demonstrating the good correlation in fission product decay in the short-term after test detonations, illustration of the effect in the long-term is important to assessment of impacts many decades after the completion of tests. An excellent set of data to illustrate the decay in external exposure rates impacted from nuclear test fallout is based on the Atomic Energy Commission (AEC) survey of the Enewetak Atoll (AEC 1973). Forty-three nuclear tests were conducted at Enewetak Atoll between 1948 and 1958. Of these, the more significant thermo-nuclear tests (e.g., magnitude of fallout) were conducted between 1952 and 1958. Tests were conducted on the northern islands of the Atoll, while southern islands of the

Atoll were support islands with only minimal impact of fallout. Figure 4-3 shows the relative location of the islands, by the AEC naming convention developed during atmospheric tests.

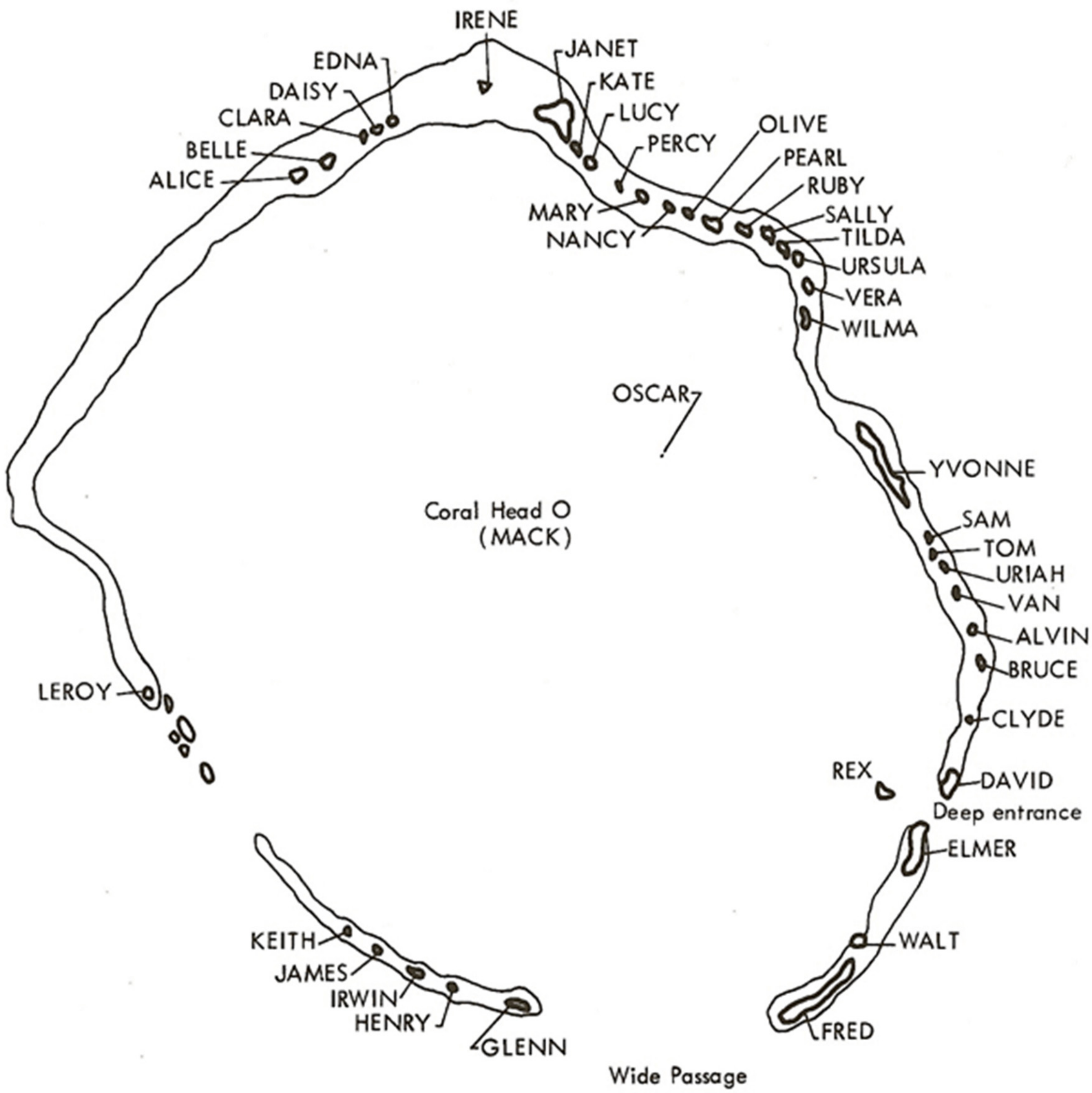


Figure 4-3. Islands of Enewetak Atoll, by AEC Naming Convention (AEC 1973).

The AEC (AEC 1973) compiled estimates of exposure rates from fallout contamination on most islands in the Atoll based on historical measurements collected during testing. By convention, all exposure rates are normalized to the predicted exposure rate at one-hour post detonation (H+1). In 1972, exposure rates on most islands were assessed by a combination of aerial and ground measurements. Each method provided isotopic-specific attribution. However, due to the minimum period between any test and the measurements in 1972 being 14 years, $^{137}Cs$ provided the most substantial contribution from residual fission products. Hence, 1972 exposure rate information is from only $^{137}$Cs. Figure 4-4 is a scatterplot of exposure rates measured in 1972 versus those predicted for all tests combined for individual islands at H+1 h. It is important to note that the y-axis exposure rates are μR $h^{-1}$, while for the x-axis the rates are R $h^{-1}$. A number of islands did not have levels of $^{137}$Cs detectable in the 1972 survey. Hence, these islands were omitted from the scatterplot. Overall, for the islands displayed in Figure 4-4, the ratio of exposure rate measured in 1972 to predicted at H+1 from all tests combined ranged from $2.1 \times 10^{-7}$ to $1.9 \times 10^{-10}$, with a median of $5.2 \times 10^{-9}$. The predicted ratios from Figure 4-1 range from 1.2 and $2.6 \times 10^{-8}$, respectively for 20 and 14 years after detonation. The green-filled data points are for islands with ratios in exposure rate close to the median, while those light blue have greater deviation from the median, but are within a factor of 2.9. The exposure rate reduction over decades is a result of both radioactive decay and environmental attenuation.

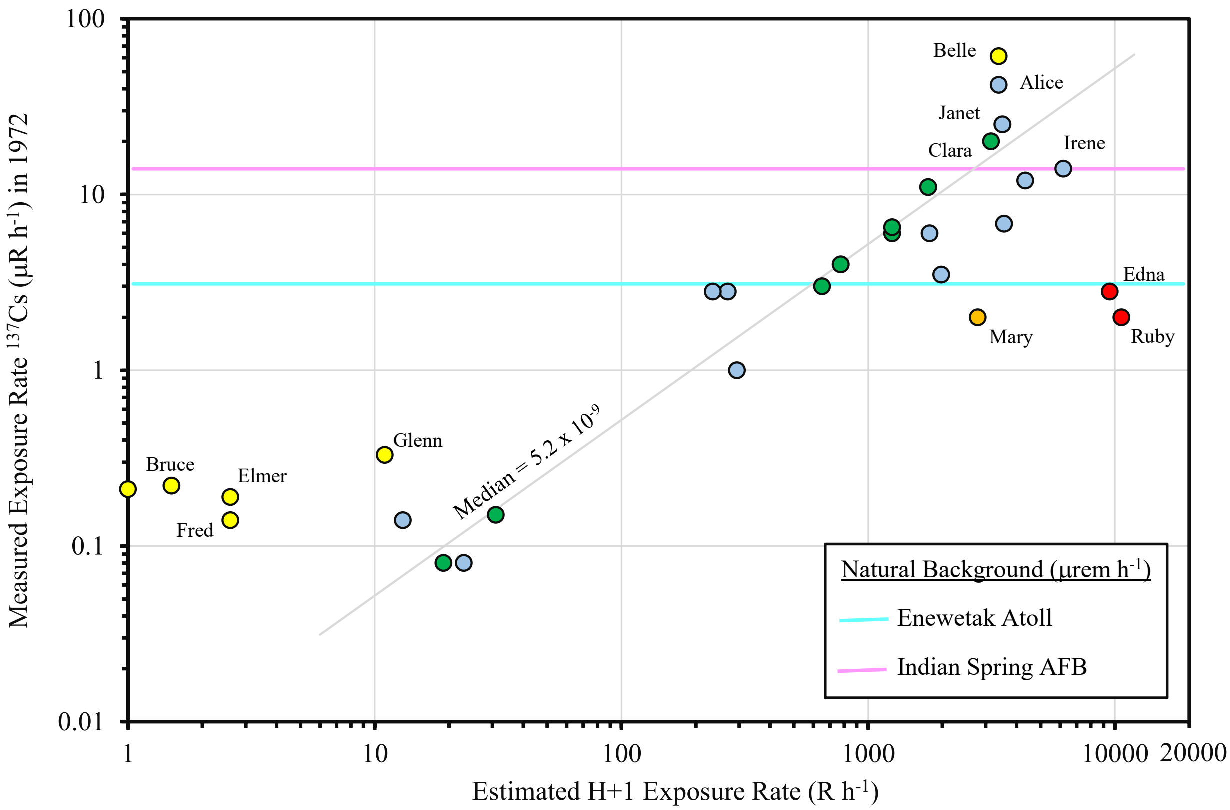


Figure 4-4. Scatterplot of Measured $^{137}$Cs Exposure Rate in 1972 Compared to H+1 from All Atmospheric Test Conducted on Enewetak Atoll for Individual Islands [Data from AC (1973)].

Over time, $^{137}$Cs and other fission products slowly migrate to greater depths in surface soils and/or undergo erosion. The latter is much more prominent for the smaller islands that had a greater degree of their land area encompassed by beaches and subsequently the effects of wave action. This is very noticeable for the islands colored in orange and red (Many, Edna, and Ruby), which had areas of only 5, 4, and 2 acres. On the other hand, the five islands with the highest ratios are colored yellow, but have the lowest estimated H+1 exposure rates. The measured exposure rates in 1972 were likely influenced to a substantial degree by fallout from Chinese nuclear tests conducted in the latter 1960s and early 1970's. Due to the short period between these tests and the 1972 AEC survey, little potential for environmental attenuation existed. Other sources of variability also exist. The time of fission product creation are varied. As noted above, the majority of fission products were produced over a six-year period. Also, there are varied $^{137}Cs$ product rates among the fission of $^{238}U$, $^{239}Pu$, and $^{235}U$. Overall, discounting these sources of variability, this data qualitatively supports the theoretical predictions shown in Figure 4-1 for long periods post detonation. Another detail on the plot are the natural background exposure rates for Enewetak Atoll and Indian Springs AFB. For the southern islands of the Enewetak Atoll, the residual $^{137}Cs$ is a small fraction of natural background, while many among the northern islands have external exposure from $^{137}Cs$ on par with natural background. Clearly, the natural background exposure rates at Indian Springs AFB are substantially higher than those at Enewetak Atoll. It is interesting to note that only five islands had exposure rates from $^{137}Cs$ greater than the natural background at Indian Springs AFB, in spite of the fact that these islands were close to ground zero of numerous thermonuclear detonations, with some conducted only 14 years prior to the AEC survey of the Atoll in 1972. Additionally, the island Janet was ground zero for three tests (not thermonuclear types).

In summary, two examples were provided in the report to illustrate the effect of radioactive decay that occurs shortly after fission product production in a nuclear detonation, and on a much longer time-scale. Both examples demonstrate reasonable adherence to theoretical expectations, with an appreciation of environmental attenuation. On a short-term basis, it is reasonable to appreciate the use of radioactive decay and isolation as a protective measure for personnel supporting operations during nuclear tests. On the long-term, the exposure rates from $^{137}Cs$ in 1972 are expected to be about $2 \times 10^{-8}$ of their value at H+1 h, without environmental attenuation. For the examples provided for islands on Enewetak Atoll, environmental attenuation provided even more reduction in exposure rates over time, though the effect is expected to be varied by the island's area. Attenuation factors in surface soils for Indian Springs AFB and many of the California AFB's that provided aircraft support for NTS tests are expected to be less pronounced than those observed for Enewetak Atoll. This is primarily due to expected difference in annual rainfall.

## 5.0 Indian Springs an Upper-Bound and Scaling Basis for Impacts from Aircraft Washdown at Other Bases

AFSEC provided the Air Force Real Property Agency an assessment of impacts to Air Force bases that provided aircraft support to NPG tests of nuclear weapons. AFSEC concluded that numerous bases of concern, e.g., McClellan AFB, Norton AFB, Castle AFB, and George AFB would have had concentrations of residual radiological contamination significantly lower than at similar washrack areas of the former Indian Springs AFB, NV. The disparity in contamination potential was two-fold. Indian Springs AFB provided ground support to a significantly larger number of aircraft missions than any other base. Secondly, Indian Springs AFB, with only a few exceptions, provided support to aircraft conducting debris sampling missions. This report provided extensive details on the stark differences in radiological contamination to aircraft that supported this type of mission compared to other missions. Penetration of the debris cloud was the key factor for contamination levels. It is clear from the data presented in this report that aircraft supported from George AFB (and many other bases) did not have radiological contamination potential of any significance compared to the debris sampling and cloud tracking aircraft supported from Indian Springs AFB.

It is difficult to provide a precise estimate of the differences in amounts of radiological contamination residuals left at the washdown areas of Indian Springs AFB compared to George AFB, or another similar base. This report provides some useful comparative data. For example, the comparison of external contamination levels on aircraft that conducted debris sampling to those that performed cloud tracking. Based on the examples from Operation Ranger, the disparity in exposure levels was approximately from 100 – 1,000-fold. Aircraft from George AFB conducted missions that had even lower contamination potential than those that performed cloud tracking. Because of this, the lack of detectable contamination on any of the aircraft that George AFB supported in Operation Upshot-Knothole is reasonable and well within expectations. In a similar manner, aircraft supported from George AFB for Operations Teapot and Plumbbob are expected to have a similar conclusion. This is due to a similarity in the support missions conducted for each respective test series.

The Air Force conducted survey of land areas on McClellan AFB, CA, Norton AFB, CA, Nellis AFB, NV, and Castle AFB, CA with negative findings of impacts from aircraft washdown areas (Rademacher 2017). This was expected because of the aircraft missions flown, limited number of aircraft missions compared to those supported from Indian Springs AFB, and the existence of fallout from global nuclear weapons tests. The latter factor is important to most radiological surveys in the environment. All surface soils contain natural radioactivity as well as contamination from global fallout from nuclear weapons tests. Assessment of radiological impacts from a specific activity, e.g., the washdown of radiological contamination from aircraft, resort to comparisons of suspect locations compared to background areas believed to be not impacted by the specific activity of concern. Among bases surveyed, residuals from washdown were only discriminable from background sources at Indian Springs AFB. This is based on findings from 1992 and 2009-2010 surveys (Rademacher 2017).

The 2009-2010 survey contained a comprehensive aerial survey completed by the DOE of the flightline and adjacent areas of the former Indian Springs AFB and more localized ground-based surveys of targeted survey areas at various locations around the flightline (Dewey 2011). Figure 5-1 contains a plot of two surveyed areas on the edge of the flightline from Dewey (2011), while Figure 5-2 contains a plot of data from another surveyed area at the end of the runway. Survey data displayed in green corresponds to γ-radiation count rates within three standard deviations of background, while the red points are those where the rates are in excess of three standard deviations above background. The survey concluded that there was no evidence of areas with widespread enhanced concentrations of $^{137}$Cs in surface soils, which was based on the DOE aerial and ground-based γ-radiation surveys. The ground-based survey confirmed small areas of enhanced concentrations of $^{137}$Cs in surface soils. Soil samples were collected from four survey unit areas that flanked parts of the runway, as well as the background are that was assumed not impacted by washdown operations. A summary of soil sample results are in Table 5-1. The mean concentrations of $^{137}$Cs in survey unit (SU) 1 were 33% higher than the background area, while the mean in SU 3 and SU 4 were about nine and 2.3-fold higher, respectively. The sample with the highest $^{137}$Cs activity concentration, 1.0 pCi g$^{-1}$, was in SU 3.

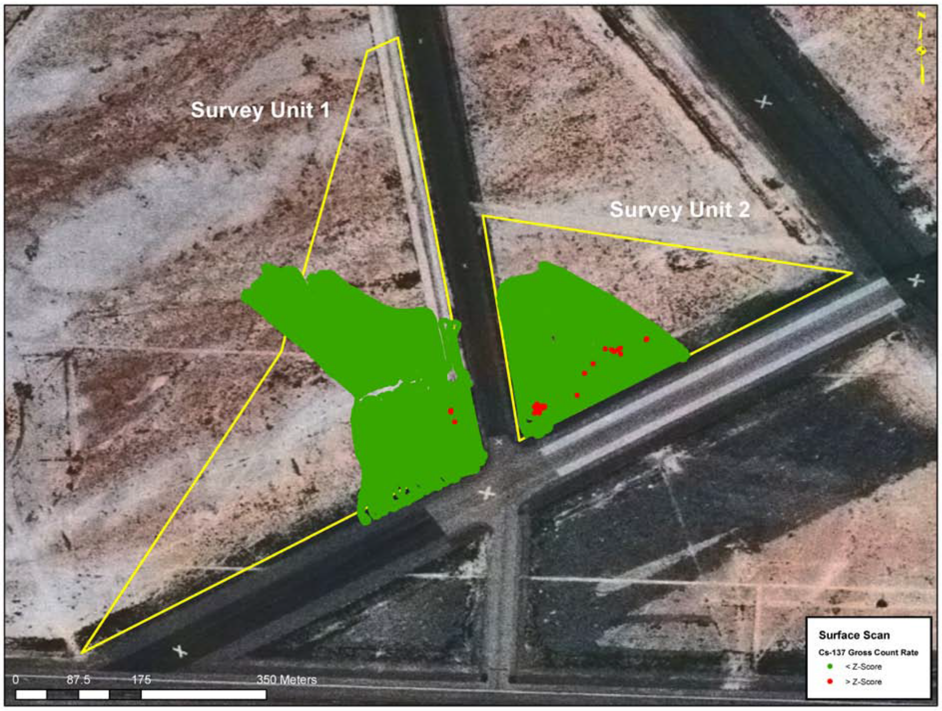


Figure 5-1. Scanning Results for Survey Units 1 and 2 from USAFSAM 2009/2010 Creech AFB Survey (Dewey 2011).


Figure 5-2. Scanning Results for Survey Unit 4 from USAFSAM 2009/2010 Creech AFB Survey (Dewey 2011).

This sample was one of two that also had detectable levels of $^{241}$Am, a decay product of un-burned plutonium fuel. The other sample was a sub-surface sample, also from SU 3, which had respective $^{137}$Cs and $^{241}$Am activity concentrations of 0.13 ± 0.02 and 0.05 ± 0.02 pCi $g^{-1}$. $^{241}$Am was also detected in a surface soil sample collected from Indian Springs AFB in a 1992 survey conducted by the Air Force (Table 2-7, Rademacher 2017). This sample had respective $^{137}$Cs and $^{241}$Am activity concentrations of 3.5 ± 0.2 and 1.65 ± 0.013 pCi $g^{-1}$.

TABLE 5-1. Summary of Surface Soil Sample Analyses from USAFSAM 2009-2010 Survey [Data from Dewey (2011)].

| Parameter | | Survey Area | | | | |
|---|---|---|---|---|---|---|
| | | Background | SU 1 | SU 2 | SU 3 | SU 4 |
| Sample No. | | 30 | 13 | 12 | 4 | 11 |
| $^{137}$Cs (pCi $g^{-1}$) | Mean | 0.033 | 0.044* | 0.025* | 0.30 | 0.075* |
| | Maximum | 0.10 | 0.080 | 0.052 | 1.0† | 0.51 |
| | Minimum | 0.011 | < 0.020 | < 0.020 | 0.011 | 0.01 |
| | Standard Deviation | 0.023 | 0.026* | 0.013* | 0.47 | 0.15* |
| | Median | 0.02 | 0.040* | 0.020* | 0.09 | 0.02* |
| % Coefficient of Variation | | 68 | 58 | 51 | 158 | 204 |

* Parameter calculated under assumption that values reported as less than (<) are equivalent to that value
† Sample had detectable levels of $^{241}$Am: 0.19 ± 0.06 pCi $g^{-1}$

Though Dewey (2011) noted small areas with enhanced concentrations of $^{137}$Cs, the report concluded that the mean concentrations of $^{137}$Cs in the survey units of interest were well below Nuclear Regulatory Commission (NRC) screening levels for residential use[2]. Table 5-18 of Rademacher (2017) contains a listings of NRC screening levels for key elements, including $^{137}$Cs, 11 pCi $g^{-1}$, at $P_{crit} = 0.10$. Current and potential future uses of land are in important issue in health assessments. Residential uses pose the most restrictive scenario due to high occupancy factors and multiple potential exposure pathways for residents. For these areas on the former Indian Springs AFB, residential uses were deemed highly unlikely. For that matter, these areas had and are expected in the future to have very limited occupancy by workers.

Data from the former Indian Springs AFB has been applied by the Air Force for impacts of contamination from aircraft washdowns at other bases, including George AFB. Due the disparity in radiological impacts expected to be perhaps 1,000-fold lower at these bases, as compared to the former Indian Springs AFB, concentrations of $^{137}$Cs is surface soils from aircraft washdown are expected to be indiscriminable from background.

[2] NRC screening levels are commonly applied as an industry-accepted standard to sites with radiological contaminants as an initial point of evaluation for potential impacts to health, though the NRC does not have regulatory jurisdiction over this source of contamination.

## 6.0 Concentrations of Radiological Contaminants at Indian Springs AFB, 1972 and Prior

This report has provided data for contaminated aircraft supporting atmospheric tests at the NTS in the early 1950's, ground-based fallout data for islands of Enewetak Atoll normalized to H+1 h after detonations, and for islands at Enewetak Atoll in 1972, 14 to 20 years after key thermonuclear tests. Radiological contamination levels at soil areas flanking the runway at the former Indian Springs AFB were provided from a 2009-2010 survey, while some soil sample data from a 1992 survey was noted. Because many of the health claims from former George AFB are based on presence of individuals at the base in the 1970's and 1980's, it is reasonable to extrapolate data from the most recent surveys to 1972. This year was chosen because it coincides with a wealth of fallout data from the AEC survey work conducted on Enewetak Atoll.

The average concentration of $^{137}$Cs is SU 3 was 0.3 pCi $g^{-1}$ in 2010, while the maximum among the four samples was 1.0 pC $g^{-1}$. We will assume an effective half-value concentration from Beck *et al.* (2010) of 12 y for $^{137}$Cs. This value includes environmental attenuation and radiological decay, as recommended for work at Enewetak and Bikini Atolls. This value was also used by Rademacher (2019) for dose estimates for personnel at Enewetak Atoll. Because environmental attenuation is expected to be higher at the Atolls than Indian Springs AFB, this is a conservative (high-sided) estimate for $^{137}$Cs concentrations in 1972. The calculated factor is 9.0, which provides an estimated average concentration in SU 3 of 2.7 pCi $g^{-1}$, and 9.0 for the sample with the maximum concentration of $^{137}$Cs is SU 3.

The estimated average concentration of $^{137}$Cs at SU 3 is placed into context of average concentrations of $^{137}$Cs on islands of Enewetak Atoll, based on data from AEC (1973). Figure 6-1 provides a scatterplot of average $^{137}$Cs in surface soils to mean measured $^{137}$Cs by in-situ $\gamma$-spectrometry. A regression line is added. Compared to Figure 4-4, this plot only contains data for one southern island, Elmer. Islands with land areas less than or equal to 6 acres are colored orange, and illustrate the in-situ measurement bias noted by the AEC for small islands (AEC 1973). The data points for these islands are above the regression line. The gold-colored line is equivalent to the average estimated concentration of $^{137}$Cs in surface soils in SU 3 (1972), which is similar to the island Ursula. The predicted external exposure rate from $^{137}$Cs is about 3 μR $h^{-1}$, which is nearly equivalent to the exposure rate from natural background sources at the Enewetak Atoll, but only about a 20% increase in the natural background exposure rate at Indian Springs AFB. The equivalence to Ursula is interesting, as this island was used as a residence island for workers conducting operations on the northern islands of the Atoll during the 1977 to 1980 cleanup. The island was chosen due to its adequate size and only minor radiological impacts from atmospheric tests conducted previously. The total average exposure rate from fallout was 5 μR $h^{-1}$ was 1972, which is dominated by the $^{137}$Cs contribution, and secondarily with 1.8 μR $h^{-1}$ from $^{60}$Co, an activation product. Besides these two contaminants, the other key radionuclides in soil samples from Ursula were $^{90}$Sr and $^{239+240}$Pu with mean concentrations of 8.3 and 1.8 pCi $g^{-1}$, respectively. Many of the samples from Ursula had non-detects for $^{241}$Am. Rademacher (2019) estimated the mean $^{241}$Am to be only 0.6 pCi $g^{-1}$, one-third the $^{239+240}$Pu. None of these contributes much to external exposure, with their major exposure path being internal radiation exposure, which commonly occurs through inhalation and ingestion pathways.

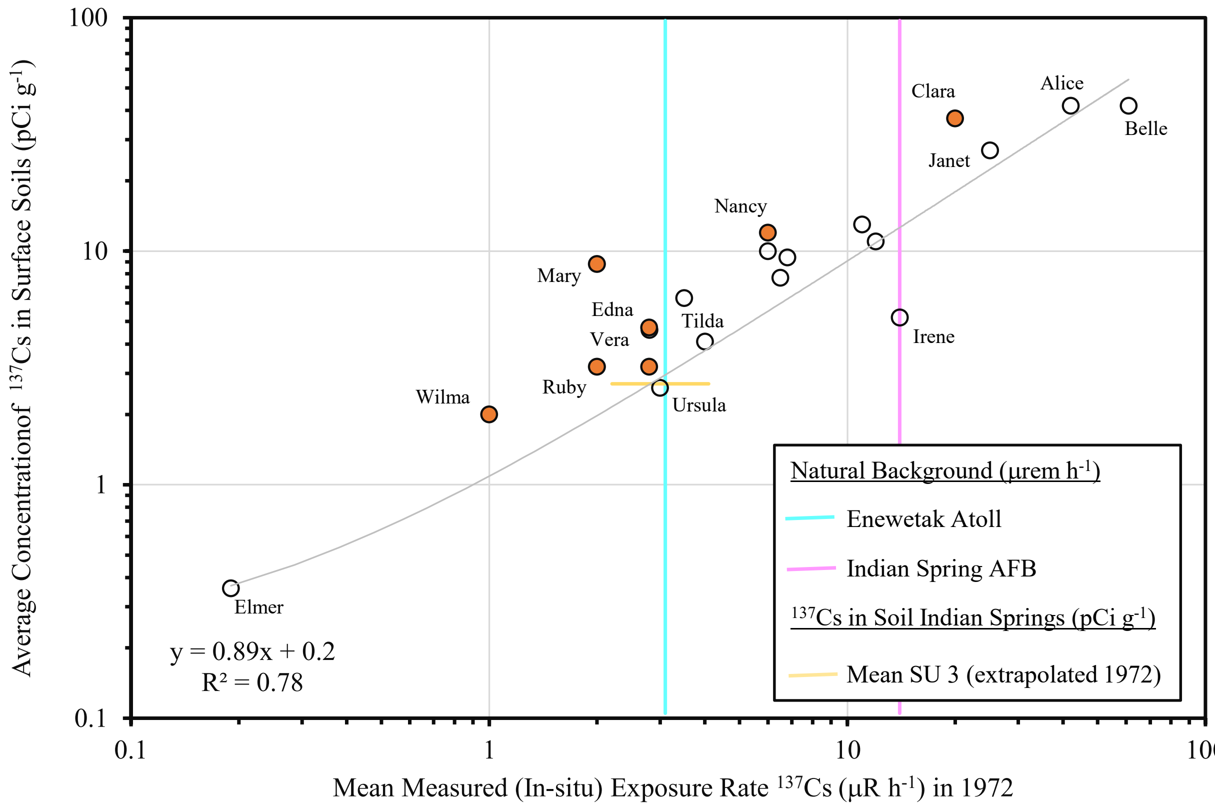


Figure 6-1. Scatterplot of Average $^{137}$Cs Measured in Surface Soil Samples vs. Average $^{137}$Cs by In-situ γ-Spectrometry [Data as Summarized in Rademacher (2019) from AEC (1973)].

Using the NRC screening values summarized in Table 5-8 of Rademacher (2017), the sum of fractions of the screening values for $P_{crit}$=0.10 is:

$$Sum = \frac{C_{Cs-137}}{S_{Cs-137}} + \frac{C_{Co-60}}{S_{Co-60}} + \frac{C_{Sr-90}}{S_{Sr-90}} + \frac{C_{Pu-239+240}}{S_{Pu-239+240}} + \frac{C_{Am-241}}{S_{Am-241}} = \frac{2.7}{11} + \frac{0.46}{3.8} + \frac{8.3}{1.7} + \frac{1.8}{2.3} + \frac{0.6}{2.1} = 6.3$$

where $C_x$ are soil concentrations and $S_x$ are screening values. This summation is commonly applied to multiple radionuclide contaminants, with the exposure goal being a value less than unity. This analysis is for a residential use scenario, where high occupancy factors and multiple exposure pathways are assumed. In reality, none of the soil areas that flanked the runway at Indian Springs AFB had any continuous presence of workers. Rather, areas around runways have restricted access and presence of individuals only for intermittent maintenance activities. The contribution to the sum of ratios by $^{90}$Sr is 77%. The screening value for this radionuclide is dominated by the ingestion of food grown on contaminated land exposure pathway. This exposure pathway did not exist at the locations around the runway.

The evaluation above is an estimated source term for SU 3, based on data from Enewetak Atoll and extrapolation of $^{137}$Cs concentrations from 2009-2010 data. Actual concentrations may have varied by perhaps a factor of two to three. Similarly, the NRC screening values quoted are for the most restrictive use scenario. Actual occupancy by personnel was expected to be at most 10% of a residential scenario. Most importantly, the analysis in this section is purposed for scaling to likely residual concentrations at George and other AFBs that provided only minor aerial support to NTS tests. As noted above, 1,000 is a reasonable scaling factor for impacts to equivalent areas on Indian Springs AFB and George AFB. This factor includes the scaled difference between contamination on aircraft completing debris sampling mission vs. cloud tracking, reduced radiological impacts for aircraft staged from George AFB and cloud tracking mission, and the difference in aircraft sorties supported from George AFB and debris sampling sorties conducted from Indian Springs. Notably, with the exception of Operation Ranger, Indian Springs had supported washdown operations on debris sampling sorties for all other NPG tests. In contrast, George AFB only provided support for three series of tests, but only for a smaller set of individual tests. In this light, the small factors of uncertainty introduced in the estimates of activity concentrations of key fallout radioisotopes are insignificant. Hence, the concentrations of radionuclides that existed in 1972 at George AFB in aircraft washdown areas would also have been indiscriminable from global sources of fallout.

Figure 6-2 provides a visual depiction of extrapolated and scaled exposure rates for Indian Springs and George AFB. This plot is based on similar principles to the extrapolations and scaling discussed above for concentrations of fallout products in surface soil, but is more pertinent to exposure issues for fission products, as external radiation exposure is a dominant dose pathway. The plot is based initially on predicted exposure rates from the average $^{137}$Cs concentrations in surface soils of SU3 from the 2009-2010 survey of suspected aircraft washdown areas of Indian Springs AFB. The estimated exposure rate for free-air is based on estimates from Rademacher (2019) for data evaluated for Enewetak Atoll (solid blue circle). Similar to the extrapolation of $^{137}$Cs concentration in soils for Indian Springs from 2010 to 1972, the same factor of about nine is depicted by the dashed-green line. The open-green circle datum is the estimated average exposure for SU3 in 1972. This estimated exposure rate is scaled to George AFB by a factor of 1,000, as illustrate by the solid-filled green circle datum. The solid-filled triangular datum includes estimated exposure from all key fission products expected to exist with $^{137}$Cs in reasonably high concentrations in 1972. Similarly, we have used data for the island Ursula from Rademacher (2019) for these estimated contributions. The only two fission products with any important contributions to exposure were $^{90}$Sr and $^{155}$Eu, though each individually only added about 5% to total exposure from fission products. From the plot, it is apparent that $^{137}$Cs dominated external exposure rates in 1972 from fission products, as the two datum are overlapped. The plot also contains two horizontal lines – one depicting exposure conditions from natural background sources at George AFB and the other for Indian Springs AFB. Clearly, the estimated exposure rates in 1972 from fission products attributed to aircraft are a miniscule fraction of those from natural background sources. This analysis provides an appreciation of the difficulty is assessing the impacts of these extremely small contributions to external exposures in light of sources that are natural to the environment. From 1972, the plot provides an extrapolation of contributions from fission products to exposure back in time to 1953 and 1958, using the relationship in the solid curve from Figure 4-1 (right plot). The two extremes of dates were provided, as this was the range of test series supported with aircraft from George AFB (Upshot-Knothole – 1953 and Plumbbob – 1958). Additionally, it was assumed, an environmental attenuation factor, as used in the extrapolation of $^{137}$Cs concentration from 2010

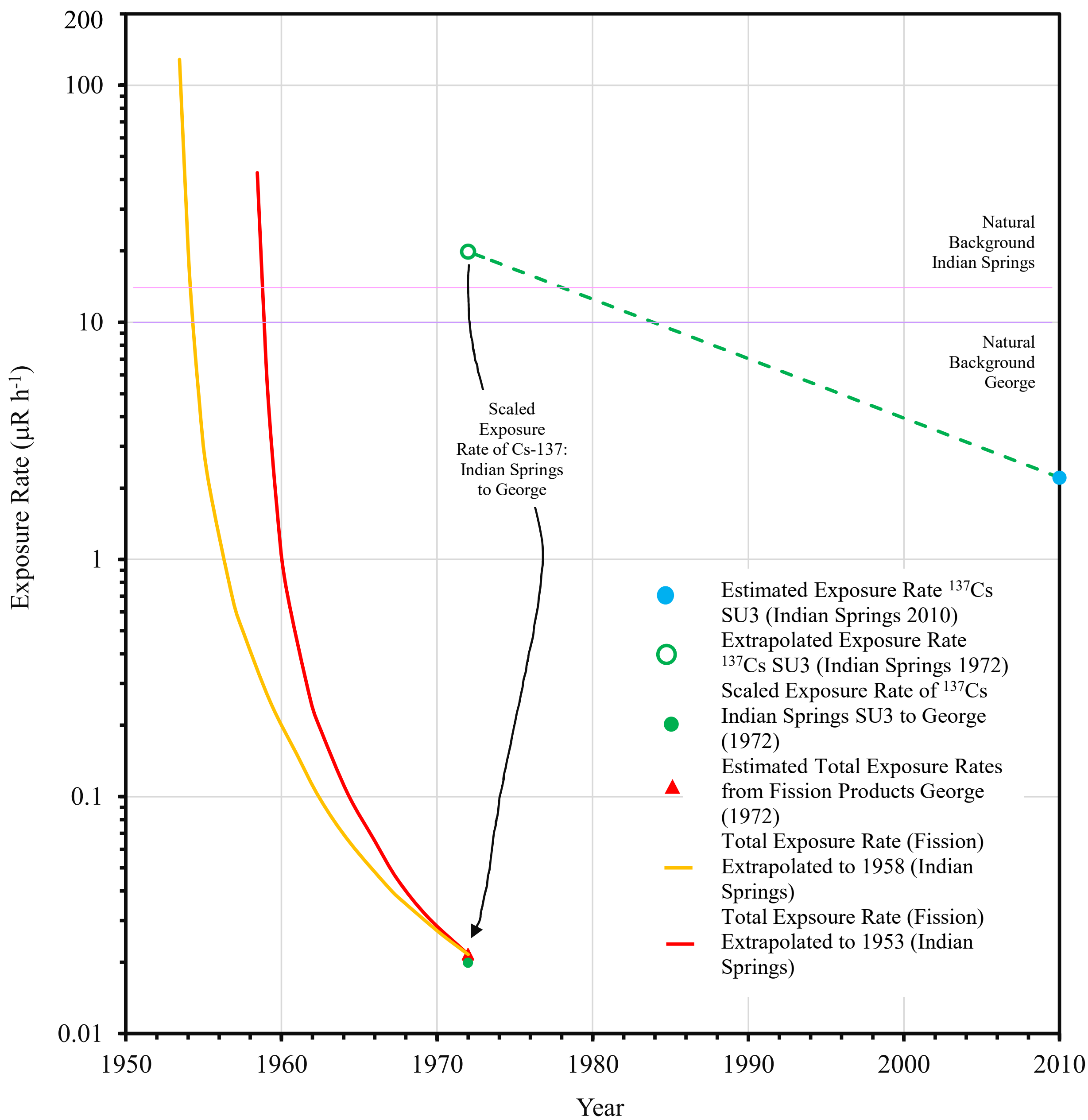


Figure 6-2. External Dose Rate Estimates for George and Indian Springs AFBs from Aircraft Contamination Washdown Operations, Based on/or Scaled from Average $^{137}Cs$ Concentration in SU3 from the 2009-2010 Survey at Indian Springs AFB, and Enewetak Atoll Radiological Data from the AEC (1973).

to 1972[3]. The two lines were extrapolated to a time six-months after detonation. It is impractical to extrapolate to periods closer to an individual test, as contamination would have been accumulated over many tests, hence rendering any specific time less significant. The endpoints

[3] The environmental attenuation factor alone provides an approximate half-concentration in soil period of 20 y.

of each curve represent exposure rates above the natural background rate for George AFB. These levels of exposures would have been near the detection limit in use by survey crews supporting these operations. An important point regarding the extrapolations, a number of conservative assumptions were used. Actual concentrations are expected to be lower. As a basis for comparison to NRC screening levels[4] discussed above, an appropriate annual limit for external exposures only would be 25 mrad $y^{-1}$, which is approximately 25 mR $y^{-1}$. Naturally, as noted above, occupancy factors for personnel in areas flanking the flightline would have been very low during operational periods of George AFB. Members of the public would have had access restrictions to these areas, as is the case for most operational runways.

## 7.0 Conclusions

The AFSEC consulted with the AF Real Property in the mid-2000's on the potential for residual radiological contaminants is surface soils that support washdown activities on aircraft that participated in atmospheric nuclear weapons tests at NTS. The primary focus was on AFBs in California that were completing BRAC activities: Norton, McClellan, George, and Castle AFBs. AFSEC determined that there was a significant difference in aircraft mission support at Indian Springs AFB, as compared to other bases than provided only minor support by mission numbers. Additionally, and most important, with only minor exceptions, nuclear debris cloud sample missions were based from Indian Springs AFB. These aircraft had radiological contamination levels 100 to 100-fold higher than cloud tracking missions. Other aircraft missions had even lower contamination. This report provides more detailed information on these points than was contained in previous AFSEC reviews (Rademacher 2017).

The last key issue regarding radiological contamination residuals at AFBs that supported aircraft for NPG test is the issue of radioactive decay. Though radioactive contamination created by nuclear detonations contains some long-lived radioactive materials, the vast majority decay shortly after creation. Under these circumstances, key radiation safety practices for individuals supporting nuclear tests were high radiation levels that persisted shortly after the detonation. This report provides two sets of examples to illustrate this point for fission products. The first example was based on surveys of aircraft in Operation Ranger that completed debris sampling and cloud tracking missions. The comparisons were between initial surveys and ones accomplished a day later. The second example was based on decay of fallout on the islands of Enewetak Atoll, where the majority of the fallout was produced between 14 and 20 years post detonation. For both of these examples, decay in exposure rates followed theoretical expectations. For the case of Enewetak Atoll, environmental attenuation also contributed to exposure rate reduction over time. These specific examples provide additional support for the conclusions drawn in Rademacher (2017) for the radiological impacts from aircraft washdown activities. This report provided extrapolation of radiological data collected in 2009-2010 to 1972 for Indian Springs AFB. While concentrations of $^{137}Cs$ were estimated to be about nine-fold in 1972 and other radiological contaminants attributed to aircraft washdown would have been

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[4] The NRC License Termination Rule was promulgated in 1997, thereby establishing the 25 mrad $y^{-1}$ criteria for external exposure sources. Prior to this, the NRC adhered to a 100 mrad $y^{-1}$ criteria for members of the public due to external radiation from NRC licensed sources. The NRC premised use of 25 mrad $y^{-1}$ under the potential that multiple sites could impact a member of the pubic, and that the combination of multiple impacts were unlikely to exceed four. Prior to 1991, the NRC had a 500 mrad $y^{-1}$ criterion for members of the public.

present, it was shown that these levels scaled to the operations at George AFB would have been indiscriminable from background sources. This conclusion is logical, and supported by a historical document documenting the aircraft washdown operations conducted at George AFB in support of Operation Upshot-Knothole, where it was noted,

> "*Training of personnel involved was considered invaluable in spite the fact that no aircraft or person was actually contaminated* (Delashaw and Lovell 1953)."

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## Appendix A

## Exposure Rates of B-29 Aircraft used in Cloud Sampling and Cloud Tracking Missions

| | |
|---|---|
| **Test Name** | Able |
| **Aircraft Code** | Queball #1 |
| **Aircraft label on graph** | Able-1 |
| **Aircraft Tail #** | 521833 |
| **Aircraft Type** | B-29 |
| **Date** | 27 Jan 1951 |
| **Mission Type** | Debris Cloud Sampling |
| | |
| **Highest Intensity (mR/hr)** | 2500 |
| **Lowest Intensity (mR/hr)** | 170 |
| **Average Intensity (mR/hr)** | 727 |

| Survey Location | Survey Reading (mR/hr) |
|---|---|
| Wing tip | 130 |
| Leading edge wing | 275 |
| Turbo and exhaust | 1100 |
| Propeller tips | 296 |
| Propeller hubs | 500 |
| Air intake | 2300 |
| Turbo and exhaust | 1000 |
| Wheel well | 600 |
| Propeller tip | 350 |
| Propeller hub | 600 |
| Air intake | 2500 |
| Air duct | 1900 |
| Pitot tube (2) | 200 |
| Nose | 375 |
| Nose wheel | 200 |
| Pitot tube (1) | 190 |
| Air duct | 2150 |
| Air intake | 2450 |
| Propeller hub | 400 |
| Propeller tip | 345 |
| Wheel well | 600 |
| Turbo and exhaust | 1000 |
| Air intake | 2100 |
| Propeller hubs | 440 |
| Propeller tip | 248 |
| Turbo and exhaust | 1000 |
| Leading edge wing | 360 |
| Wing tip | 170 |
| Door (rear entrance) | 340 |
| Tail skid | 320 |
| Pilot seat | 175 |
| Co-pilots seat | 195 |
| Engineers seat | 210 |
| Radar observer | 185 |
| Navigators | 195 |
| Right scanner | 240 |
| Left scanner | 249 |
| Weather | 210 |
| Radio operator | 200 |
| Lower filter | 1600 |
| Upper filter | 1900 |

| | |
|---|---|
| **Test Name** | Able |
| **Aircraft Code** | Queball #2 |
| **Aircraft label on graph** | Able-2 |
| **Aircraft Tail #** | 521831 |
| **Aircraft Type** | B-29 |
| **Date** | 27 Jan 1951 |
| **Mission Type** | Debris Cloud Sampling |
| | |
| **Highest Intensity (mR/hr)** | 500 |
| **Lowest Intensity (mR/hr)** | 280 |
| **Average Intensity (mR/hr)** | 163 |

| Survey Location | Survey Reading (mR/hr) |
|---|---|
| Wing tip | 30 |
| Leading edge wing | 40 |
| Turbo and exhaust | 250 |
| Propeller tips | 0.05 |
| Propeller hubs | 70 |
| Air intake | 420 |
| Turbo and exhaust | 240 |
| Wheel well | 140 |
| Propeller tip | 100 |
| Propeller hub | 170 |
| Air intake | 495 |
| Air duct | 200 |
| Pitot tube (2) | 38 |
| Nose | 39 |
| Nose wheel | 28 |
| Pitot tube (1) | 35 |
| Air duct | 435 |
| Air intake | 400 |
| Propeller hub | 90 |
| Propeller tip | 85 |
| Wheel well | 160 |
| Turbo and exhaust | 240 |
| Air intake | 490 |
| Propeller hubs | 160 |
| Propeller tip | 145 |
| Turbo and exhaust | 240 |
| Leading edge wing | No Record |
| Wing tip | No Record |
| Door (rear entrance) | No Record |
| Tail skid | No Record |
| Pilot seat | No Record |
| Co-pilots seat | No Record |
| Engineers seat | No Record |
| Radar observer | No Record |
| Navigators | No Record |
| Right scanner | No Record |
| Left scanner | No Record |
| Weather | No Record |
| Radio operator | No Record |
| Lower filter | No Record |
| Upper filter | No Record |

| | |
|---|---|
| **Test Name** | Baker |
| **Aircraft Code** | Queball #1 |
| **Aircraft label on graph** | Baker |
| **Aircraft Tail #** | 521833 |
| **Aircraft Type** | B-29 |
| **Date** | 29 Jan 1951 |
| **Mission Type** | Debris Cloud Sampling |
| | |
| **Highest Intensity (mR/hr)** | 850 |
| **Lowest Intensity (mR/hr)** | 20 |
| **Average Intensity (mR/hr)** | 162 |

| Survey Location | Survey Reading (mR/hr) |
|---|---|
| Wing tip | 80 |
| Leading edge wing | 80 |
| Turbo and exhaust | 220 |
| Propeller tips | 80 |
| Propeller hubs | 70 |
| Air intake | 450 |
| Turbo and exhaust | 220 |
| Wheel well | 150 |
| Propeller tip | 80 |
| Propeller hub | 100 |
| Air intake | 400 |
| Air duct | 160 |
| Pitot tube (2) | 60 |
| Nose | 30 |
| Nose wheel | 20 |
| Pitot tube (1) | 60 |
| Air duct | 175 |
| Air intake | 400 |
| Propeller hub | 100 |
| Propeller tip | 100 |
| Wheel well | 175 |
| Turbo and exhaust | 205 |
| Air intake | 450 |
| Propeller hubs | 150 |
| Propeller tip | 105 |
| Turbo and exhaust | 220 |
| Leading edge wing | 75 |
| Wing tip | 50 |
| Door (rear entrance) | 80 |
| Tail skid | 60 |
| Pilot seat | 40 |
| Co-pilots seat | 38 |
| Engineers seat | 48 |
| Radar observer | 50 |
| Navigators | 58 |
| Right scanner | 55 |
| Left scanner | 58 |
| Weather | 55 |
| Radio operator | 60 |
| Lower filter | 700 |
| Upper filter | 850 |

| | |
|---|---|
| **Test Name** | Easy |
| **Aircraft Code** | Queball #1 |
| **Aircraft label on graph** | Easy-1 |
| **Aircraft Tail #** | 521831 |
| **Aircraft Type** | B-29 |
| **Date** | 1 Feb 1951 |
| **Mission Type** | Debris Cloud Sampling |
| | |
| **Highest Intensity (mR/hr)** | 680 |
| **Lowest Intensity (mR/hr)** | 36 |
| **Average Intensity (mR/hr)** | 154 |

| **Survey Location** | **Survey Reading (mR/hr)** |
|---|---|
| Wing tip | 80 |
| Leading edge wing | 80 |
| Turbo and exhaust | 100 |
| Propeller tips | 60 |
| Propeller hubs | 80 |
| Air intake | 400 |
| Turbo and exhaust | 260 |
| Wheel well | 100 |
| Propeller tip | 80 |
| Propeller hub | 90 |
| Air intake | 400 |
| Air duct | 260 |
| Pitot tube (2) | 70 |
| Nose | 120 |
| Nose wheel | 150 |
| Pitot tube (1) | 70 |
| Air duct | 270 |
| Air intake | 430 |
| Propeller hub | 110 |
| Propeller tip | 90 |
| Wheel well | 100 |
| Turbo and exhaust | 190 |
| Air intake | 440 |
| Propeller hubs | 120 |
| Propeller tip | 90 |
| Turbo and exhaust | 240 |
| Leading edge wing | 80 |
| Wing tip | 80 |
| Door (rear entrance) | 50 |
| Tail skid | 60 |
| Pilot seat | 42 |
| Co-pilots seat | 36 |
| Engineers seat | 40 |
| Radar observer | 36 |
| Navigators | 40 |
| Right scanner | 40 |
| Left scanner | 50 |
| Weather | 50 |
| Radio operator | 50 |
| Lower filter | 510 |
| Upper filter | 680 |

| | |
|---|---|
| **Test Name** | Easy |
| **Aircraft Code** | Queball #2 |
| **Aircraft label on graph** | Easy-2 |
| **Aircraft Tail #** | 521833 |
| **Aircraft Type** | B-29 |
| **Date** | 1 Feb 1951 |
| **Mission Type** | Debris Cloud Sampling |
| | |
| **Highest Intensity (mR/hr)** | 600 |
| **Lowest Intensity (mR/hr)** | 40 |
| **Average Intensity (mR/hr)** | 179 |

| Survey Location | Survey Reading (mR/hr) |
|---|---|
| Wing tip | 90 |
| Leading edge wing | 90 |
| Turbo and exhaust | 190 |
| Propeller tips | 100 |
| Propeller hubs | 105 |
| Air intake | 600 |
| Turbo and exhaust | 200 |
| Wheel well | 100 |
| Propeller tip | 100 |
| Propeller hub | 100 |
| Air intake | 450 |
| Air duct | 350 |
| Pitot tube (2) | 100 |
| Nose | 80 |
| Nose wheel | 40 |
| Pitot tube (1) | 100 |
| Air duct | 200 |
| Air intake | 500 |
| Propeller hub | 150 |
| Propeller tip | 110 |
| Wheel well | 100 |
| Turbo and exhaust | 210 |
| Air intake | 600 |
| Propeller hubs | 130 |
| Propeller tip | 100 |
| Turbo and exhaust | 200 |
| Leading edge wing | 90 |
| Wing tip | 90 |
| Door (rear entrance) | 140 |
| Tail skid | 160 |
| Pilot seat | 50 |
| Co-pilots seat | 50 |
| Engineers seat | 50 |
| Radar observer | 40 |
| Navigators | 50 |
| Right scanner | 50 |
| Left scanner | 70 |
| Weather | 70 |
| Radio operator | 70 |
| Lower filter | 560 |
| Upper filter | 600 |

| | |
|---|---|
| **Test Name** | Baker-2 |
| **Aircraft Code** | Queball #1 |
| **Aircraft label on graph** | Baker-2 |
| **Aircraft Tail #** | 44-27344A |
| **Aircraft Type** | B-29 |
| **Date** | 2 Feb 1951 |
| **Mission Type** | Debris Cloud Sampling |
| | |
| **Highest Intensity (mR/hr)** | 480 |
| **Lowest Intensity (mR/hr)** | 22 |
| **Average Intensity (mR/hr)** | 148 |

| Survey Location | Survey Reading (mR/hr) |
|---|---|
| Wing tip | 27 |
| Leading edge wing | 43 |
| Turbo and exhaust | 250 |
| Propeller tips | 110 |
| Propeller hubs | 95 |
| Air intake | 360 |
| Turbo and exhaust | 280 |
| Wheel well | 110 |
| Propeller tip | 100 |
| Propeller hub | 100 |
| Air intake | 400 |
| Air duct | 200 |
| Pitot tube (2) | 70 |
| Nose | 22 |
| Nose wheel | 24 |
| Pitot tube (1) | 60 |
| Air duct | 210 |
| Air intake | 400 |
| Propeller hub | 100 |
| Propeller tip | 110 |
| Wheel well | 110 |
| Turbo and exhaust | 300 |
| Air intake | 400 |
| Propeller hubs | 105 |
| Propeller tip | 140 |
| Turbo and exhaust | 300 |
| Leading edge wing | 60 |
| Wing tip | 34 |
| Door (rear entrance) | 90 |
| Tail skid | 150 |
| Pilot seat | 32 |
| Co-pilots seat | 34 |
| Engineers seat | 42 |
| Radar observer | 50 |
| Navigators | 60 |
| Right scanner | 50 |
| Left scanner | 30 |
| Weather | 42 |
| Radio operator | 50 |
| Lower filter | 420 |
| Upper filter | 460 |

| | |
|---|---|
| **Test Name** | Fox |
| **Aircraft Code** | Queball #1 |
| **Aircraft label on graph** | Fox-1 |
| **Aircraft Tail #** | 263459 |
| **Aircraft Type** | B-29 |
| **Date** | 6 Feb 1951 |
| **Mission Type** | Debris Cloud Sampling |
| | |
| **Highest Intensity (mR/hr)** | 420 |
| **Lowest Intensity (mR/hr)** | 34 |
| **Average Intensity (mR/hr)** | 170 |

| **Survey Location** | **Survey Reading (mR/hr)** |
|---|---|
| Wing tip | 135 |
| Leading edge wing | 135 |
| Turbo and exhaust | 100 |
| Propeller tips | 180 |
| Propeller hubs | 110 |
| Air intake | 400 |
| Turbo and exhaust | 300 |
| Wheel well | 100 |
| Propeller tip | 100 |
| Propeller hub | 110 |
| Air intake | 400 |
| Air duct | 300 |
| Pitot tube (2) | 100 |
| Nose | 140 |
| Nose wheel | 160 |
| Pitot tube (1) | 100 |
| Air duct | 200 |
| Air intake | 450 |
| Propeller hub | 150 |
| Propeller tip | 110 |

| | |
|---|---|
| Wheel well | 100 |
| Turbo and exhaust | 300 |
| Air intake | 320 |
| Propeller hubs | 150 |
| Propeller tip | 100 |
| Turbo and exhaust | 250 |
| Leading edge wing | 250 |
| Wing tip | 300 |
| Door (rear entrance) | 100 |
| Tail skid | 150 |
| Pilot seat | 40 |
| Co-pilots seat | 40 |
| Engineers seat | 45 |
| Radar observer | 45 |
| Navigators | 45 |
| Right scanner | 60 |
| Left scanner | 60 |
| Weather | 34 |
| Radio operator | 50 |
| Lower filter | 400 |
| Upper filter | 420 |

| | |
|---|---|
| **Test Name** | Fox |
| **Aircraft Code** | Queball #2 |
| **Aircraft label on graph** | Fox-2 |
| **Aircraft Tail #** | 521833 |
| **Aircraft Type** | B-29 |
| **Date** | 6 Feb 1951 |
| **Mission Type** | Debris Cloud Sampling |
| | |
| **Highest Intensity (mR/hr)** | 290 |
| **Lowest Intensity (mR/hr)** | 18 |
| **Average Intensity (mR/hr)** | 54 |

| Survey Location | Survey Reading (mR/hr) |
|---|---|
| Wing tip | 18 |
| Leading edge wing | 20 |
| Turbo and exhaust | 70 |
| Propeller tips | 45 |
| Propeller hubs | 47 |
| Air intake | 110 |
| Turbo and exhaust | 70 |
| Wheel well | 40 |
| Propeller tip | 45 |
| Propeller hub | 48 |
| Air intake | 100 |
| Air duct | 40 |
| Pitot tube (2) | 29 |
| Nose | 20 |
| Nose wheel | 20 |
| Pitot tube (1) | 22 |
| Air duct | 40 |
| Air intake | 90 |
| Propeller hub | 48 |
| Propeller tip | 50 |
| Wheel well | 40 |
| Turbo and exhaust | 60 |
| Air intake | 95 |
| Propeller hubs | 50 |
| Propeller tip | 48 |
| Turbo and exhaust | 50 |
| Leading edge wing | 22 |
| Wing tip | 24 |
| Door (rear entrance) | 15 |
| Tail skid | 20 |
| Pilot seat | 26 |
| Co-pilots seat | 27 |
| Engineers seat | 27 |
| Radar observer | 28 |
| Navigators | 28 |
| Right scanner | 28 |
| Left scanner | 28 |
| Weather | 27 |
| Radio operator | 28 |
| Lower filter | 260 |
| Upper filter | 290 |

| | |
|---|---|
| **Test Name** | Fox |
| **Aircraft Code** | Shortimer Able |
| **Aircraft label on graph** | Fox-A |
| **Aircraft Tail #** | 521872 |
| **Aircraft Type** | B-29 |
| **Date** | 6 Feb 1951 |
| **Mission Type** | Debris Cloud Tracking |
| | |
| **Highest Intensity (mR/hr)** | .05 |
| **Lowest Intensity (mR/hr)** | .05 |
| **Average Intensity (mR/hr)** | .05 |

| Survey Location | Survey Reading (mR/hr) |
|---|---|
| Wing tip | 0.05 |
| Leading edge wing | 0.05 |
| Turbo and exhaust | 0.05 |
| Propeller tips | 0.05 |
| Propeller hubs | 0.05 |
| Air intake | 0.05 |
| Turbo and exhaust | 0.05 |
| Wheel well | 0.05 |
| Propeller tip | 0.05 |
| Propeller hub | 0.05 |
| Air intake | 0.05 |
| Air duct | 0.05 |
| Pitot tube (2) | 0.05 |
| Nose | 0.05 |
| Nose wheel | 0.05 |
| Pitot tube (1) | 0.05 |
| Air duct | 0.05 |
| Air intake | 0.05 |
| Propeller hub | 0.05 |
| Propeller tip | 0.05 |

| | |
|---|---|
| Wheel well | 0.05 |
| Turbo and exhaust | 0.05 |
| Air intake | 0.05 |
| Propeller hubs | 0.05 |
| Propeller tip | 0.05 |
| Turbo and exhaust | 0.05 |
| Leading edge wing | 0.05 |
| Wing tip | 0.05 |
| Door (rear entrance) | 0.05 |
| Tail skid | 0.05 |
| Pilot seat | 0.05 |
| Co-pilots seat | 0.05 |
| Engineers seat | 0.05 |
| Radar observer | 0.05 |
| Navigators | 0.05 |
| Right scanner | 0.05 |
| Left scanner | 0.05 |
| Weather | 0.05 |
| Radio operator | 0.05 |
| Lower filter | 0.05 |
| Upper filter | 0.05 |

| | |
|---|---|
| **Test Name** | Fox |
| **Aircraft Code** | No Record |
| **Aircraft label on graph** | Fox-B |
| **Aircraft Tail #** | 521831 |
| **Aircraft Type** | B-29 |
| **Date** | 7 Feb 1951 |
| **Mission Type** | Debris Cloud Tracking |
| | |
| **Highest Intensity (mR/hr)** | 1.5 |
| **Lowest Intensity (mR/hr)** | .05 |
| **Average Intensity (mR/hr)** | .05 |

| Survey Location | Survey Reading (mR/hr) |
|---|---|
| Wing tip | 0.05 |
| Leading edge wing | 0.05 |
| Turbo and exhaust | 1.0 |
| Propeller tips | 0.05 |
| Propeller hubs | 0.05 |
| Air intake | 1.0 |
| Turbo and exhaust | 1.0 |
| Wheel well | .05 |
| Propeller tip | .05 |
| Propeller hub | .05 |
| Air intake | 1.5 |
| Air duct | .05 |
| Pitot tube (2) | .05 |
| Nose | .05 |
| Nose wheel | .05 |
| Pitot tube (1) | .05 |
| Air duct | .05 |
| Air intake | 1.5 |
| Propeller hub | 0.05 |
| Propeller tip | 0.05 |

| | |
|---|---|
| Wheel well | 0.05 |
| Turbo and exhaust | 1.0 |
| Air intake | 1.5 |
| Propeller hubs | 0.05 |
| Propeller tip | 0.05 |
| Turbo and exhaust | 1.0 |
| Leading edge wing | 0.05 |
| Wing tip | 0.05 |
| Door (rear entrance) | 0.05 |
| Tail skid | 0.05 |
| Pilot seat | 0.05 |
| Co-pilots seat | 0.05 |
| Engineers seat | 0.05 |
| Radar observer | 1.0 |
| Navigators | 0.05 |
| Right scanner | .05 |
| Left scanner | 0.05 |
| Weather | 0.05 |
| Radio operator | 0.05 |
| Lower filter | 0.05 |
| Upper filter | 0.05 |

| | |
|---|---|
| **Test Name** | Fox |
| **Aircraft Code** | |
| **Aircraft label on graph** | Fox-C |
| **Aircraft Tail #** | 44-86399 |
| **Aircraft Type** | B-29 |
| **Date** | 6 Feb 1951 |
| **Mission Type** | Debris Cloud Tracking |
| | |
| **Highest Intensity (mR/hr)** | 0.05 |
| **Lowest Intensity (mR/hr)** | 0.05 |
| **Average Intensity (mR/hr)** | 0.05 |

| Survey Location | Survey Reading (mR/hr) |
|---|---|
| Wing tip | 0.05 |
| Leading edge wing | 0.05 |
| Turbo and exhaust | 0.05 |
| Propeller tips | 0.05 |
| Propeller hubs | 0.05 |
| Air intake | 0.05 |
| Turbo and exhaust | 0.05 |
| Wheel well | 0.05 |
| Propeller tip | 0.05 |
| Propeller hub | 0.05 |
| Air intake | 0.05 |
| Air duct | 0.05 |
| Pitot tube (2) | 0.05 |
| Nose | 0.05 |
| Nose wheel | 0.05 |
| Pitot tube (1) | 0.05 |
| Air duct | 0.05 |
| Air intake | 0.05 |
| Propeller hub | 0.05 |
| Propeller tip | 0.05 |
| Wheel well | 0.05 |
| Turbo and exhaust | 0.05 |
| Air intake | 0.05 |
| Propeller hubs | 0.05 |
| Propeller tip | 0.05 |
| Turbo and exhaust | 0.05 |
| Leading edge wing | 0.05 |
| Wing tip | 0.05 |
| Door (rear entrance) | 0.05 |
| Tail skid | 0.05 |
| Pilot seat | 0.05 |
| Co-pilots seat | 0.05 |
| Engineers seat | 0.05 |
| Radar observer | 0.05 |
| Navigators | 0.05 |
| Right scanner | 0.05 |
| Left scanner | 0.05 |
| Weather | 0.05 |
| Radio operator | 0.05 |
| Lower filter | 0.05 |
| Upper filter | 0.05 |

# Appendix B

## Flight Descriptions For Aircraft Staging From George AFB

***Simulated Bomb Delivery***

| Test | Shot | Flight Description | References |
|---|---|---|---|
| Teapot | Moth | ➢ Three F-84's established their positions by orbiting 8 km from the shot tower of altitudes 25,000 – 28,000 feet. One minute before the detonation, the aircraft made a 55 degree delivery dive descending to from 17,000 – 20,000 feet. The aircraft then turned away from GZ in anticipation of the shock wave<br>➢ Three F-84's performed a BT-9 maneuver. They entered from the NE and SE of GZ at 22,000 feet. They entered into a shallow dive directly over ground zero. At 8,000 feet, they performed their simulated bomb drop delivery. Then the aircraft veered off, reformed, and returned to base | (Maag *et al* 1981a) Page 62 |
| Teapot | Tesla | ➢ Three F-84's simulated a BT-9 mission. At the time of the shot, the aircraft were located about 9 km (5.5 miles) east of the detonation at an altitude of 15,000 – 17,500 feet. The aircraft left the test area within ten minutes of the shot.<br>➢ Three F-84 completed similar flight paths, except performed dive bombing missions. All aircraft were expected to receive less than one calories thermal and less than 0.15 psi. | (Maag *et al* 1981a) Page 90-91 |
| Teapot | Turk | ➢ Six F-84's established orbit about 110 – 130 km (68-80 miles) northeast of GZ. They flew at altitudes of 28,000-29,000 feet on a west-bound vector towards the test site.<br>➢ Two minutes before detonation, the aircraft descended to altitudes ranging from 26,000 – 19,000 feet. Within 8 km (5 miles) of GZ, the planes swung to the north before the blast wave arrived. After, they returned to base. | (Maag *et al* 1981a) Page 120 |
| Teapot | Hornet | ➢ 12 F-84's established orbit about 110 – 130 km (68-80 miles) northeast of GZ at altitudes of 28,000-29,000 feet on west-bound vector towards the test site.<br>➢ Two minutes before detonation, the aircraft descended to altitudes ranging from 26,000 – 19,000 feet. Within 8 km (5 miles) of GZ, the planes swung to the north before the blast wave arrived. After the blast wave, they returned to their base of operation. | (Maag *et al* 1981a) Page 146 |
| Teapot | Bee | ➢ Four F-84's aircraft established position 110 - 130 km east of GZ. Then flew at 28 - 29k ft on a 270 degree vector toward NTS.<br>➢ Two minutes before detonation, the aircraft descended from 28 - 19k ft. Within 8 km of GZ, the planes tuned to a heading of 360 heading until the blast wave arrived. After the weave, they returned to base. | (Maag *et al* 1981b) Page 90-91 |
| Teapot | Ess | ➢ Eight F-84 aircraft flew low altitude bombing exercises and dive bombing maneuvers over the test site at the time of detonation. The aircraft performed these maneuvers two miles from the nuclear cloud. They could not approach the cloud any closer because of high radiation intensities within the cloud.<br>➢ They left the area 10 minutes after the detonation | (Ponton *et al* 1981a) Page 52 |
| Teapot | Apple 1 | ➢ Thirteen F-84 aircraft entered the shot area at 28,000 feet altitude, 32 km (20 miles) NE of ground zero, then descended to 18,000 feet, 8 km (5 miles) north of ground zero.<br>➢ At the time of the detonation, the aircraft turned right (NW) and flew out of the area. | (Ponton *et al* 1981a) Page 86 |
| Teapot | Wasp Prime | ➢ Thirteen F-84's performed their fly by maneuver 8 km (5 miles) north of ground zero at shot time at an altitude of about 18,000 – 22,000.<br>➢ At the time of detonation, they broke away to the north and then returned to base | (Ponton *et al* 1981a) Page 110 |
| Teapot | Zucchini | ➢ Four F-9F's performed a flyby maneuver. The planes established their positions by orbiting 110-130 km (68-80 miles) NE of GZ.<br>➢ Two minutes before the detonation, the aircraft ascended to altitudes ranging from 26,000 feet to 19,000 feet, and flew toward the shot area. Within eight km of GZ, the planes swing to the north until the arrival of the blast wave. After the blast arrival, the four aircraft returned to base. | (Ponton *et al* 1981a) Page 214 |

***IBDA***

| Test | Shot | Flight Description | Reference |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Upshot-Knothole | Encore | ➢ Twelve B-36 aircraft and eight F-84 aircraft reached the test area at 37,000 feet. The aircraft flew information for about 40 minutes over the test site to simulate strike and support activities. While over the test site, crews tested IBDA equipment and familiarized themselves with operations pertaining to the use of nuclear weapons. | (Massie *et al* 1981a) Page 58 |
| Upshot-Knothole | Grable | ➢ Twelve B-36 aircraft and eight F-84 aircraft reached the test area at 37,000 feet. The aircraft flew information for about over the test site for about 60 minutes to simulate strike and support activities. While over the test site, crews tested IBDA equipment and familiarized themselves with operations pertaining to the use of nuclear weapons. | (Massie *et al* 1981a) Page 149 |
| Teapot | Turk | ➢ Three RB-47's made passes tangential to ground zero at altitudes ranging from 34,500 feet to 39,000 feet in order to train crews to evaluate bomb damage assessment equipment during bomb drop and aerial nuclear detonation exercises.<br>➢ One RB-47 flew directly over ground zero at 40,000 feet | (Maag *et al* 1981a) Page 120 |
| ***Photographic Reconnaissance*** | | | |
| **Test** | **Shot** | **Flight Description** | **Reference** |
| Upshot-Knothole | Encore | ➢ Three RF-80 aircraft took off about one hour after the shot and began an orbit at an altitude of 30,000 feet.<br>➢ Two hours after the detonation, the first RF-80 made a photography run over the ground zero target and returned to the orbit point. The second and third aircraft also made runs over the target area and returned to the orbit point. | (Massie *et al* 1981a) Page 60 |
| Plumbbob | Boltzman, Franklin, Lassen, Wilson | ➢ Two RF-84F aircraft orbited the test site at 31,000 feet until the shot was fired. Upon clearance from the Air Operations Center, they began the photographic mission, flying towards GZ. They closed the shot area approximately 15 minutes after the detonation at an altitude of 10,000 feet.<br>➢ Upon completion of the run, they left the area and returned to base. | (West *et al* 1981) Page 33-34, 57, 76, 105-106 |
| Plumbbob | Priscilla | ➢ Two RF-84F aircraft flew to the NTS where they orbited above Lathrop Wells at 31,000 feet until the shot was detonated. Upon clearance from the Air Operations Center, they began a photographic mission toward ground zero. They crossed the shot area approximately 15 minutes after the detonation at an altitude of 10,000 feet. Upon completion of the run, they returned to base | (Viscuso *et al* 1981) Page 58 |
| Plumbbob | Diablo, Kepler, Owens | ➢ Two RF-84F aircraft flew a holding pattern until ten minutes after the detonation, when they made a photographic run over ground zero at 10,000 feet. Upon completion of the run, they left the area and returned to base. | (Maag and Ponton 1981) Page 37, 74, 96 |
| Plumbbob | Charleston | ➢ One T-33 aircraft passed over ground zero ten minutes after the detonation at an altitude of 10,000 feet to photograph the nuclear target. | Massie and Ponton 1981) Page 99 |
| Plumbbob | Smokey | ➢ Two RF-84F aircraft orbited at 20,000 – 30,000 feet. After the detonation, the pilots flew under the mushroom cloud at 3,000 – 4,000 feet at 440 knots. They only made one photo-reconnaissance pass, spending only a few minutes in the area of the cloud. | (Harris *et al* 1981*)* Page 76 |
| Plumbbob | Galileo | ➢ Two RF-84F aircraft flew a right-hand elliptical course from Beatty to Lathrop Wells, at an inbound heading of 127 degrees true and an altitude of 31,000 feet.<br>➢ After the detonation, the two aircraft were directed by the Air Operations Center to proceed to the Galileo area to position themselves for a timed pass over ground zero at 10,000 feet. The pass was to occur ten minutes after detonation. Upon completing the mission, the aircraft returned to base | (Ponton *et al* 1981b) Page 43 |
| ***Nike Missile Signal Attenuation*** | | | |
| **Test** | **Shot** | **Flight Description** | **References** |
| Plumbbob | Priscilla | ➢ A B-26 tested the attenuation of a Nike missile control signals when operating in or beyond a nuclear cloud. Beginning 30 minutes before the detonation, the plane flew an oval race-track course north of ground zero at an altitude of 15,000 feet.<br>➢ After the shot, the pilot positioned the aircraft so that the radioactive cloud was between the aircraft and an equipment site to monitor the Nike Control signs | (Viscuso *et al* 1981) Page |

| | | | |
|---|---|---|---|
| Plumbbob | Diablo | ➢ A B-26 positioned itself so that the cloud was between the aircraft and the Nike Hercules ground site. The aircraft was 15 miles from the balloon at the time of the detonation and spent about 30 minutes in the area | (Maag and Ponton 1981) Page 25 |
| Plumbbob | Kepler | ➢ At the time of the detonation, a B-26 positioned itself so that the cloud was between the aircraft and a Nike Hercules ground site. The aircraft was 15 nautical miles (17 miles) from GZ, and spent 30 minutes in the area | (Maag and Ponton 1981) Page 66 |
| Plumbbob | Owens | ➢ A B-26 positioned itself so that the cloud was between the aircraft and the Nike Hercules ground site. The aircraft was 15 miles from the balloon at the time of the detonation and spent about 30 minutes in the area | (Maag and Ponton 1981) Page 85 |
| Plumbbob | Stokes | ➢ A B-26 aircraft positioned itself so that the cloud was between the aircraft and a Nike ground site at the time of detonation. The B-26 was about 20 km (12.5 miles) NE of GZ at the time of the detonation, and spent about 30 minutes in the area | (Maag and Ponton 1981) Page 109 |
| Plumbbob | Shasta | ➢ A B-26 positioned itself so that the cloud was between the aircraft and a Nike Hercules ground site | (Maag and Ponton 1981) Page 125 |
| Plumbbob | Doppler, Franklin Prime | ➢ A B-26 aircraft positioned itself so that the cloud was between the aircraft and a Nike Hercules ground site about 20 km (12.5 miles) NE of GZ. The B-26 spent about 30 minutes in the area | (Maag and Ponton 1981) Page 144, 159-160 |

## Appendix C

## Complete Set of Survey Measurements for Shots Annie-Simon during Operation Upshot-Knothole

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Test Name** | Annie | Annie | Annie | Annie | Annie | Annie | Annie |
| **Aircraft Code** | Tiger Red 1 | Tiger White 2 | Tiger White 3 | Tiger Red 2 | Tiger Blue 1 | Tiger Blue 2 | Tiger Blue 3 |
| **Aircraft Tail #** | 51-1028-A | 51-1043-A | 51-1045-A | 51-1032-A | 51-1051-A | 51-1054-A | 51-1055-A |
| **Aircraft Type** | F-84 G | F-84 G | F-84 G | F-84 G | F-84 G | F-84 G | F-84 G |
| **Date** | 17-Mar-53 | 17-Mar-53 | 17-Mar-53 | 17-Mar-53 | 17-Mar-53 | 17-Mar-53 | 17-Mar-53 |
| **Detonation time (GMT)** | 13:20 | 13:20 | 13:20 | 13:20 | 13:20 | 13:20 | 13:20 |
| **Mission Type** | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling |
| **Highest Intensity Survey (mR/h)** | 400 | 1200 | 400 | 1200 | 1000 | 500 | 360 |
| **Lowest Intensity Survey (mR/h)** | 110 | 140 | 160 | 340 | 270 | 100 | 50 |
| **Average Intensity Survey (mR/h)** | 169 | 311 | 283 | 502 | 415 | 190 | 140 |
| **Median Intensity Survey (mR/h)** | 140 | 240 | 300 | 420 | 360 | 170 | 110 |
| **Total Integrated Dose** | 0.1 | 0.12 | 0.2 | 0.2 | 0.2 | 0.17 | 0.14 |
| **No. of Pass** | 1 | 1 | 2 | 2 | 2 | 1 | 2 |
| **Time entered cloud** | 16:23 | 16:00 | 15:50 | 16:57 | 16:08 | 16:57 | 15:37 |
| **Total Time in Cloud (min)** | 1.17 | 0.58 | 3.00 | 2.37 | 1.17 | 0.07 | 2.00 |
| **Time Exited Cloud** | 16:24:10 | 16:00:35 | 15:53:00 | 16:59:22 | 16:09:10 | 16:57:04 | 15:39:00 |
| **Total Time in Cloud** | 0:01:10 | 0:00:35 | 0:03:00 | 0:02:22 | 0:01:10 | 0:00:04 | 0:02:00 |
| **Median Elapsed Time in Cloud** | 00:00:35 | 00:00:17 | 00:01:30 | 00:01:11 | 00:00:35 | 00:00:02 | 00:01:00 |
| **Median Time in Cloud** | 16:23:35 | 16:00:17 | 15:51:30 | 16:58:11 | 16:08:35 | 16:57:02 | 15:38:00 |
| **Time Elapsed from DT to Median Time in Cloud** | 03:03:35 | 02:40:17 | 02:31:30 | 03:38:11 | 02:48:35 | 03:37:02 | 02:18:00 |
| **Mean time after detonation present in Cloud (hrs)** | 3.05 | 2.67 | 2.52 | 3.63 | 2.80 | 3.62 | 2.30 |
| **Decay Corrected Contamination (Normalized to Mean Collection Time)** | 189.2 | 312.8 | 471.0 | 616.8 | 678.8 | 225.4 | 160.4 |
| **Date of survey** | 17-Mar-53 | 17-Mar-53 | 17-Mar-53 | 17-Mar-53 | 17-Mar-53 | 17-Mar-53 | 17-Mar-53 |
| **Survey Time (GMT)** | 17:15 | 16:40 | 17:00 | 18:20 | 18:05 | 17:55 | 16:29 |
| **Time after detonation (hrs)** | 3.92 | 3.33 | 3.67 | 5 | 4.75 | 4.58 | 3.15 |
| **Survey Locations** | | | | | | | |
| **Air intake (6 in. inside)** | 140 | 300 | 370 | 480 | 380 | 280 | 360 |
| **Right bomb Rack** | 180 | 350 | 240 | 420 | 450 | 170 | 120 |
| **Right wing (leading edge)** | 120 | 240 | 180 | 400 | 320 | 110 | 80 |
| **Right pylon rack** | Not Reported | Not Reported | Not Reported | Not Reported | Not Reported | Not Reported | Not Reported |
| **Right wing tip** | Not Reported | Not Reported | Not Reported | Not Reported | 290 | Not Reported | Not Reported |
| **Right wing tip tank** | 150 | 140 | 300 | 340 | Not Reported | 140 | 50 |
| **Right side turbine** | 220 | 220 | 390 | 700 | 480 | 200 | 150 |
| **Right horizontal stabilizer** | 120 | 200 | 320 | 380 | 360 | 150 | 100 |
| **Tail pipe (6 in. inside)** | 140 | 250 | 300 | 400 | 360 | 180 | 110 |
| **Left horizontal stabilizer** | 120 | 240 | 270 | 480 | 300 | 170 | 90 |
| **Left Side turbine** | 210 | 270 | 340 | 500 | 480 | 220 | 120 |
| **Left wing tip tank** | 110 | 160 | 160 | 350 | 300 | 100 | 80 |
| **Left wing tip** | Not Reported | Not Reported | Not Reported | Not Reported | Not Reported | Not Reported | Not Reported |
| **Left pylon rack** | Not Reported | Not Reported | Not Reported | Not Reported | Not Reported | Not Reported | Not Reported |
| **Left wing (leading edge)** | 110 | 200 | 170 | 460 | 270 | 110 | 60 |
| **Left bomb rack** | 180 | 270 | 240 | 410 | 410 | 140 | 140 |
| **Dive brake** | 400 | 1200 | 400 | 1200 | 1000 | 500 | 360 |

| Test Name | Nancy | Nancy | Nancy | Nancy | Nancy | Nancy | Nancy | Nancy | Nancy |
|---|---|---|---|---|---|---|---|---|---|
| Aircraft Code | Tiger Red 1 | Tiger Red 2 | Tiger Red 3 | Tiger White 1 | Tiger White 2 | Tiger White 3 | Tiger Red 4 | Tiger Blue 1 | Tiger Blue 3 |
| Aircraft Tail # | 51-1028-A | 51-1032-A | 51-1037-A | 51-1042-A | 51-1043-A | 51-1045-A | 51-1049-A | 51-1051-A | 51-1055-A |
| Aircraft Type | F-84G | F-84 G | F-84 G | F-84 G | F-84 G | F-84 G | F-84 G | F-84 G | F-84 G |
| Date | 24-Mar-53 | 24-Mar-53 | 24-Mar-53 | 24-Mar-53 | 24-Mar-53 | 24-Mar-53 | 24-Mar-53 | 24-Mar-53 | 24-Mar-53 |
| Detonation time (GMT) | 13:10 | 13:10 | 13:10 | 13:10 | 13:10 | 13:10 | 13:10 | 13:10 | 13:10 |
| Mission Type | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling |
| Highest Intensity Survey (mR/h) | 1600 | 4200 | 4000 | 4000 | 500 | 1000 | 2200 | 2000 | 2200 |
| Lowest Intensity Survey (mR/h) | 260 | 800 | 800 | 1000 | 140 | 300 | 200 | 300 | 600 |
| Average Intensity Survey (mR/h) | 530 | 1567 | 1760 | 1447 | 301 | 503 | 633 | 973 | 893 |
| Median Intensity Survey (mR/h) | 340 | 1200 | 1600 | 1100 | 280 | 440 | 500 | 900 | 800 |
| Total Integrated Dose | 0.70 | 1.54 | 1.50 | 1.09 | 0.60 | 0.15 | 1.4 | 0.65 | 0.7 |
| No. of Pass | 4 | 4 | 5 | 3 | 4 | 7 | 3 | 5 | 2 |
| Time entered cloud | 16:01 | 16:00 | 16:40 | 16:36 | 17:00 | 17:15 | 18:50 | 17:26 | 18:46 |
| Total Time in Cloud (min) | 1.87 | 7.50 | 8.87 | 3.08 | 3.83 | 0.00 | 3.65 | 0.00 | 0.33 |
| Time Exited Cloud | 16:02:52 | 16:07:30 | 16:48:52 | 16:39:05 | 17:03:50 | 17:15:00 | 18:53:39 | 17:26:00 | 18:46:20 |
| Total Time in Cloud | 0:01:52 | 0:07:30 | 0:08:52 | 0:03:05 | 0:03:50 | 0:00:00 | 0:03:39 | 0:00:00 | 0:00:20 |
| Median Elapsed Time in Cloud | 00:00:56 | 00:03:45 | 00:04:26 | 00:01:33 | 00:01:55 | 00:00:00 | 00:01:49 | 00:00:00 | 00:00:10 |
| Median Time in Cloud | 16:01:56 | 16:03:45 | 16:44:26 | 16:37:33 | 17:01:55 | 17:15:00 | 18:51:49 | 17:26:00 | 18:46:10 |
| Time Elapsed from DT to Median Time in Cloud | 02:51:56 | 02:53:45 | 03:34:26 | 03:27:33 | 03:51:55 | 04:05:00 | 05:41:49 | 04:16:00 | 05:36:10 |
| Mean time after detonation present in Cloud (hrs) | 2.85 | 2.88 | 3.57 | 3.45 | 3.85 | 4.08 | 5.68 | 4.27 | 5.60 |
| Decay Corrected Contamination (Normalized to Mean Collection Time) | 536.8 | 1871.0 | 2028.2 | 1684.1 | 453.1 | 769.4 | 615.1 | 2152.2 | 1428.8 |
| Date of survey | 24-Mar-54 | 24-Mar-54 | 24-Mar-54 | 24-Mar-54 | 24-Mar-54 | 24-Mar-54 | 24-Mar-54 | 24-Mar-54 | 24-Mar-54 |
| Survey Time (GMT) | 17:20 | 17:20 | 17:31 | 18:05 | 18:55 | 19:40 | 19:55 | 20:00 | 20:15 |
| Time after detonation (hrs) | 4.17 | 4.17 | 4.35 | 4.92 | 5.75 | 6.50 | 6.75 | 8.83 | 9.08 |
| Survey Locations | | | | | | | | | |
| Air intake (6 in. inside) | 360 | 1400 | 1200 | 1000 | 220 | 350 | 650 | 900 | 700 |
| Right Inner landing gear door | 360 | 1200 | 3000 | 1000 | 240 | 440 | 400 | 800 | 800 |
| Right wing (leading edge) | 310 | 2400 | 800 | 2100 | 400 | 1000 | 550 | 1400 | 1300 |
| Right wing tip | 300 | 1000 | 2000 | 1100 | 250 | 500 | 500 | 800 | 800 |
| Right wing tip tank | 300 | 1200 | 1000 | 1000 | 180 | 300 | 500 | 600 | 600 |
| Right side turbine | 1100 | 1900 | 2000 | 1200 | 330 | 700 | 450 | 900 | 800 |
| Right horizontal stabilizer | 300 | 1100 | 1700 | 1200 | 280 | 500 | 350 | 1000 | 800 |
| Tail pipe (6 in. inside) | 800 | 800 | 1200 | 1000 | 280 | 300 | 200 | 500 | 600 |
| Left horizontal stabilizer | 300 | 1400 | 1500 | 2000 | 280 | 500 | 200 | 1000 | 600 |
| Left side turbine | 1000 | 1600 | 1800 | 1100 | 380 | 300 | 400 | 1200 | 800 |
| Left wing tip tank | 260 | 1100 | 1000 | 1000 | 140 | 360 | 500 | 300 | 700 |
| Left wing tip | 260 | 1100 | 1600 | 1000 | 230 | 400 | 500 | 800 | 700 |
| Left wing (leading edge) | 360 | 2000 | 1600 | 2000 | 500 | 700 | 1600 | 1500 | 1100 |
| Left Inner landing gear door | 340 | 1100 | 2000 | 1000 | 310 | 300 | 500 | 900 | 900 |
| Dive brake | 1600 | 4200 | 4000 | 4000 | 500 | 900 | 2200 | 2000 | 2200 |

| Test Name | Ruth | Ruth | Ruth | Ruth | Ruth | Ruth | Ruth | Ruth | Ruth |
|---|---|---|---|---|---|---|---|---|---|
| Aircraft Code | Tiger White 1 | Tiger Red 2 | Tiger Red 3 | Tiger Red 4 | Tiger Blue 2 | Tiger White 4 | Tiger Blue 3 | Tiger Blue 4 | Tiger White 3 |
| Aircraft Tail # | 51-1042-A | 51-1032-A | 51-1037-A | 51-1049-A | 51-1054-A | 51-1038-A | 51-1055-A | 51-1046-A | 51-1045-A |
| Aircraft Type | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 |
| Date | 31-Mar-53 | 31-Mar-53 | 31-Mar-53 | 31-Mar-53 | 31-Mar-53 | 31-Mar-53 | 31-Mar-53 | 31-Mar-53 | 31-Mar-53 |
| Detonation time (GMT) | 13:00 | 13:00 | 13:00 | 13:00 | 13:00 | 13:00 | 13:00 | 13:00 | 13:00 |
| Mission Type | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling |
| Highest Intensity Survey (mR/h) | 1100 | 525 | 225 | 120 | 160 | 110 | 100 | 100 | 60 |
| Lowest Intensity Survey (mR/h) | 210 | 115 | 100 | 40 | 10 | 10 | 10 | 12 | 10 |
| Average Intensity Survey (mR/h) | 550 | 288 | 166 | 80 | 61 | 49 | 31 | 32 | 28 |
| Median Intensity Survey (mR/h) | 455 | 250 | 155 | 80 | 35 | 40 | 26 | 27 | 22 |
| Total Integrated Dose | 0.45 | 0.45 | 0.2 | 0.08 | 0.1 | 0.08 | 0.1 | 0 | 0.05 |
| No. of Pass | 3 | 4 | 1 | 1 | 1 | 1 | 3 | 1 | 2 |
| Time entered cloud | 13:37 | 13:54 | 15:35 | 16:09 | 16:40 | 16:40 | 17:25 | 17:30 | 17:27 |
| Total Time in Cloud (min) | 2.67 | 3.43 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Time Exited Cloud | 13:39:40 | 13:57:26 | 15:35:00 | 16:09:00 | 16:40:00 | 16:40:00 | 17:25:00 | 17:30:00 | 17:27:00 |
| Total Time in Cloud | 0:02:40 | 0:03:26 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 |
| Median Elapsed Time in Cloud | 00:01:20 | 00:01:43 | 00:00:00 | 00:00:00 | 00:00:00 | 00:00:00 | 00:00:00 | 00:00:00 | 00:00:00 |
| Median Time in Cloud | 13:38:20 | 13:55:43 | 15:35:00 | 16:09:00 | 16:40:00 | 16:40:00 | 17:25:00 | 17:30:00 | 17:27:00 |
| Time Elapsed from DT to Median Time in Cloud | 00:38:20 | 00:55:43 | 02:35:00 | 03:09:00 | 03:40:00 | 03:40:00 | 04:25:00 | 04:30:00 | 04:27:00 |
| Mean time after detonation present in Cloud (hrs) | 0.63 | 0.92 | 2.58 | 3.15 | 3.67 | 3.67 | 4.42 | 4.50 | 4.45 |
| Decay Corrected Contamination (Normalized to Mean Collection Time) | 1465.8 | 540.8 | 262.3 | 114.6 | 49.8 | 54.5 | 34.4 | 33.8 | 30.4 |
| Date of survey | 3/31/1954 | 31-Mar-53 | 3/31/1953 | 3/31/1953 | 3/31/1953 | 3/31/1953 | 3/31/1953 | 3/31/1953 | 3/31/1953 |
| Survey Time (GMT) | 14:40 | 14:45 | 17:00 | 17:15 | 17:55 | 17:45 | 18:35 | 18:25 | 18:50 |
| Time after detonation (hrs) | 1.67 | 1.75 | 4 | 4.25 | 4.92 | 4.75 | 5.58 | 5.42 | 5.83 |
| Survey Locations | | | | | | | | | |
| Air intake (6 in. inside) | 280 | 200 | 105 | 55 | 120 | 40 | 34 | 18 | 20 |
| Right Inner landing gear door | 455 | 260 | 150 | 70 | 120 | 40 | 26 | 27 | 26 |
| Right wing (leading edge) | 800 | 420 | 200 | 95 | 140 | 80 | 48 | 38 | 46 |
| Right wing tip | 280 | 175 | 120 | 45 | 50 | 10 | 16 | 14 | 14 |
| Right wing tip tank | 220 | 135 | 100 | 40 | 10 | 25 | 10 | 12 | 10 |
| Right side turbine | 1000 | 435 | 205 | 100 | 30 | 70 | 26 | 42 | 50 |
| Right horizontal stabilizer | 410 | 220 | 140 | 75 | 15 | 40 | 14 | 22 | 18 |
| Tail pipe (6 in. inside) | 550 | 260 | 200 | 105 | 20 | 60 | 30 | 28 | 22 |
| Left horizontal stabilizer | 430 | 210 | 155 | 65 | 120 | 40 | 18 | 22 | 16 |
| Left side turbine | 1100 | 445 | 205 | 100 | 20 | 60 | 28 | 43 | 40 |
| Left wing tip tank | 210 | 115 | 120 | 60 | 60 | 34 | 20 | 18 | 10 |
| Left wing tip | 260 | 245 | 155 | 80 | 10 | 32 | 20 | 21 | 16 |
| Left wing (leading edge) | 800 | 420 | 220 | 120 | 35 | 80 | 44 | 42 | 50 |
| Left Inner landing gear door | 460 | 250 | 190 | 95 | 10 | 20 | 30 | 29 | 26 |
| Dive brake | 1000 | 525 | 225 | 100 | 160 | 110 | 100 | 100 | 60 |

| Test Name | Dixie | Dixie | Dixie | Dixie | Dixie | Dixie | Dixie | Dixie |
|---|---|---|---|---|---|---|---|---|
| Aircraft Code | Tiger Red 2 | Tiger Blue 2 | Tiger Red 1 | Tiger Red 3 | Tiger White 1 | Tiger Red 4 | Tiger White 4 | Tiger Blue 4 |
| Aircraft Tail # | 51-1032-A | 51-1054-A | 51-1028-A | 51-1037-A | 51-1042-A | 51-1049-A | 51-1038-A | 51-1046-A |
| Aircraft Type | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 |
| Date | 6-Apr-53 | 6-Apr-53 | 6-Apr-53 | 6-Apr-53 | 6-Apr-53 | 6-Apr-53 | 6-Apr-53 | 6-Apr-53 |
| Detonation time (GMT) | 15:30 | 15:30 | 15:30 | 15:30 | 15:30 | 15:30 | 15:30 | 15:30 |
| Mission Type | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling |
| Highest Intensity Survey (mR/h) | 900 | 190 | 165 | 300 | 145 | 300 | 100 | 210 |
| Lowest Intensity Survey (mR/h) | 150 | 30 | 60 | 80 | 32 | 80 | 16 | 80 |
| Average Intensity Survey (mR/h) | 529 | 86 | 114 | 180 | 94 | 148 | 43 | 133 |
| Median Intensity Survey (mR/h) | 600 | 90 | 120 | 180 | 100 | 125 | 44 | 130 |
| Total Integrated Dose | 0.8 | 0.17 | 0.2 | 0.15 | 0.2 | 0.19 | 0.08 | 1 |
| No. of Pass | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 2 |
| Time entered cloud | 16:45 | 16:48 | 17:54 | 17:55 | 18:12 | 18:30 | 18:51 | 18:45 |
| Total Time in Cloud (min) | 2.17 | 3.00 | 0.58 | 2.40 | 0.20 | 2.00 | 0.03 | 0.17 |
| Time Exited Cloud | 16:47:10 | 16:51:00 | 17:54:35 | 17:57:24 | 18:12:12 | 18:32:00 | 18:51:02 | 18:45:10 |
| Total Time in Cloud | 0:02:10 | 0:03:00 | 0:00:35 | 0:02:24 | 0:00:12 | 0:02:00 | 0:00:02 | 0:00:10 |
| Median Elapsed Time in Cloud | 00:01:05 | 00:01:30 | 00:00:17 | 00:01:12 | 00:00:06 | 00:01:00 | 00:00:01 | 00:00:05 |
| Median Time in Cloud | 16:46:05 | 16:49:30 | 17:54:17 | 17:56:12 | 18:12:06 | 18:31:00 | 18:51:01 | 18:45:05 |
| Time Elapsed from DT to Median Time in Cloud | 01:16:05 | 01:19:30 | 02:24:17 | 02:26:12 | 02:42:06 | 03:01:00 | 03:21:01 | 03:15:05 |
| Mean time after detonation present in Cloud (hrs) | 1.27 | 1.32 | 2.40 | 2.43 | 2.70 | 3.02 | 3.35 | 3.25 |
| Decay Corrected Contamination (Normalized to Mean Collection Time) | 1210.9 | 193.7 | 54.9 | 271.3 | 161.7 | 313.6 | 65.6 | 316.9 |
| Date of survey | 6-Apr-53 | 6-Apr-53 | 6-Apr-53 | 6-Apr-53 | 6-Apr-53 | 6-Apr-53 | 6-Apr-53 | 6-Apr-53 |
| Survey Time (GMT) | 17:47 | 18:00 | 16:45 | 18:55 | 19:32 | 20:00 | 20:10 | 20:20 |
| Time after detonation (hrs) | 2.28 | 2.5 | 1.25 | 3.42 | 4.03 | 6.5 | 4.67 | 6.83 |
| Survey Locations | | | | | | | | |
| Air intake (6 in. inside) | 310 | 60 | 90 | 120 | 80 | 120 | 26 | 110 |
| Right Inner landing gear door | 380 | 90 | 120 | 145 | 100 | 145 | 60 | 130 |
| Right wing (leading edge) | 520 | 100 | 150 | 157 | 120 | 200 | 60 | 170 |
| Right wing tip | 250 | 33 | 85 | 200 | 65 | 125 | 24 | 80 |
| Right wing tip tank | 165 | 30 | 60 | 180 | 35 | 100 | 60 | 90 |
| Right side turbine | 900 | 190 | 150 | 300 | 140 | 300 | 45 | 170 |
| Right horizontal stabilizer | 600 | 70 | 120 | 150 | 100 | 80 | 60 | 120 |
| Tail pipe (6 in. inside) | 750 | 120 | 110 | 200 | 110 | 110 | 28 | 140 |
| Left horizontal stabilizer | 700 | 70 | 110 | 140 | 90 | 80 | 18 | 130 |
| Left side turbine | 900 | 150 | 140 | 300 | 130 | 80 | 46 | 170 |
| Left wing tip tank | 150 | 30 | 60 | 80 | 32 | 125 | 16 | 80 |
| Left wing tip | 210 | 33 | 85 | 120 | 42 | 100 | 24 | 90 |
| Left wing (leading edge) | 700 | 100 | 130 | 180 | 110 | 210 | 44 | 170 |
| Left Inner landing gear door | 600 | 90 | 135 | 200 | 105 | 180 | 34 | 140 |
| Dive brake | 800 | 120 | 165 | 230 | 145 | 270 | 100 | 210 |

| Test Name | Ray | Ray | Ray | Ray | Ray | Ray | Ray | Ray | Ray |
|---|---|---|---|---|---|---|---|---|---|
| Aircraft Code | Tiger White 2 | Tiger Red 4 | Tiger Blue 1 | Tiger Blue 2 | Tiger Red 2 | Tiger White 4 | Tiger White 1 | Tiger White 3 | Tiger Blue 4 |
| Aircraft Tail # | 51-1043-A | 51-1049-A | 51-1051-A | 51-1054-A | 51-1032-A | 51-1038-A | 51-1042-A | 51-1045-A | 51-1046-A |
| Aircraft Type | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 |
| Date | 11-Apr-53 | 11-Apr-53 | 11-Apr-53 | 11-Apr-53 | 11-Apr-53 | 11-Apr-53 | 11-Apr-53 | 11-Apr-53 | 11-Apr-53 |
| Detonation time (GMT) | 12:45 | 12:45 | 12:45 | 12:45 | 12:45 | 12:45 | 12:45 | 12:45 | 12:45 |
| Mission Type | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling |
| Highest Intensity Survey (mR/h) | 420 | 800 | 1200 | 1400 | 120 | 100 | 140 | 165 | 44 |
| Lowest Intensity Survey (mR/h) | 60 | 160 | 80 | 85 | 26 | 18 | 16 | 20 | 10 |
| Average Intensity Survey (mR/h) | 216 | 409 | 250 | 310 | 76 | 42 | 62 | 80 | 26 |
| Median Intensity Survey (mR/h) | 180 | 360 | 140 | 240 | 80 | 33 | 60 | 80 | 24 |
| Total Integrated Dose | 0.4 | 0.37 | 0.09 | 0.1 | 0.03 | 0.3 | 0 | 0.1 | 0.04 |
| No. of Pass | 2 | 3 | 3 | 3 | 4 | 4 | 5 | 4 | 2 |
| Time entered cloud | 13:30 | 13:42 | 15:04 | 15:04 | 15:29 | 15:29 | 15:54 | 15:52 | 15:58 |
| Total Time in Cloud (min) | 1.50 | 1.92 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Time Exited Cloud | 13:31:30 | 13:43:55 | 15:04:02 | 15:04:00 | 15:29:00 | 15:29:00 | 15:54:00 | 15:52:00 | 15:58:00 |
| Total Time in Cloud | 0:01:30 | 0:01:55 | 0:00:02 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 |
| Median Elapsed Time in Cloud | 00:00:45 | 00:00:58 | 00:00:01 | 00:00:00 | 00:00:00 | 00:00:00 | 00:00:00 | 00:00:00 | 00:00:00 |
| Median Time in Cloud | 13:30:45 | 13:42:58 | 15:04:01 | 15:04:00 | 15:29:00 | 15:29:00 | 15:54:00 | 15:52:00 | 15:58:00 |
| Time Elapsed from DT to Median Time in Cloud | 00:45:45 | 00:57:58 | 02:19:01 | 02:19:00 | 02:44:00 | 02:44:00 | 03:09:00 | 03:07:00 | 03:13:00 |
| Mean time after detonation present in Cloud (hrs) | 0.75 | 0.95 | 2.32 | 2.32 | 2.73 | 2.73 | 3.15 | 3.12 | 3.22 |
| Decay Corrected Contamination (Normalized to Mean Collection Time) | 792.8 | 2483.5 | 223.0 | 359.7 | 114.1 | 48.3 | 84.0 | 119.2 | 31.1 |
| Date of survey | 11-Apr-53 | 11-Apr-53 | 11-Apr-53 | 11-Apr-53 | 11-Apr-53 | 11-Apr-53 | 11-Apr-53 | 11-Apr-53 | 11-Apr-53 |
| Survey Time (GMT) | 15:20 | 15:30 | 16:10 | 16:00 | 16:25 | 16:30 | 16:55 | 17:06 | 16:45 |
| Time after detonation (hrs) | 2.58 | 4.75 | 3.42 | 3.25 | 3.67 | 3.75 | 4.17 | 4.35 | 4 |
| Survey Locations | | | | | | | | | |
| Air intake (6 in. inside) | 100 | 220 | 120 | 110 | 60 | 22 | 22 | 35 | 18 |
| Right Inner landing gear door | 180 | 430 | 210 | 240 | 80 | 33 | 43 | 80 | 28 |
| Right wing (leading edge) | 240 | 700 | 340 | 250 | 110 | 46 | 90 | 110 | 36 |
| Right wing tip | 80 | 260 | 100 | 110 | 60 | 23 | 24 | 55 | 18 |
| Right wing tip tank | 60 | 160 | 80 | 90 | 32 | 21 | 16 | 20 | 15 |
| Right side turbine | 325 | 650 | 340 | 450 | 100 | 70 | 100 | 140 | 44 |
| Right horizontal stabilizer | 80 | 270 | 120 | 160 | 60 | 23 | 60 | 70 | 14 |
| Tail pipe (6 in. inside) | 180 | 360 | 190 | 310 | 80 | 60 | 70 | 80 | 24 |
| Left horizontal stabilizer | 90 | 270 | 120 | 160 | 65 | 24 | 60 | 60 | 14 |
| Left side turbine | 420 | 600 | 380 | 480 | 100 | 80 | 90 | 140 | 44 |
| Left wing tip tank | 80 | 190 | 80 | 85 | 26 | 18 | 19 | 22 | 10 |
| Left wing tip | 300 | 230 | 100 | 110 | 60 | 19 | 24 | 32 | 17 |
| Left wing (leading edge) | 400 | 600 | 140 | 400 | 110 | 48 | 95 | 110 | 40 |
| Left Inner landing gear door | 300 | 390 | 230 | 290 | 80 | 41 | 70 | 80 | 25 |
| Dive brake | 400 | 800 | 1200 | 1400 | 120 | 100 | 140 | 165 | 38 |

| Test Name | Badger | Badger | Badger | Badger | Badger | Badger | Badger | Badger |
|---|---|---|---|---|---|---|---|---|
| Aircraft Code | Tiger Blue 1 | Tiger White 3 | Tiger Red 4 | Tiger Red 1 | Tiger White 2 | Tiger White 4 | Tiger Blue 3 | Tiger Red 3 |
| Aircraft Tail # | 51-1051-A | 51-1045-A | 51-1049-A | 51-1028-A | 51-1043-A | 51-1038-A | 51-1055-A | 51-1037-A |
| Aircraft Type | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 |
| Date | 18-Apr-53 | 18-Apr-53 | 18-Apr-53 | 18-Apr-53 | 18-Apr-53 | 18-Apr-53 | 18-Apr-53 | 18-Apr-53 |
| Detonation time (GMT) | 12:35 | 12:35 | 12:35 | 12:35 | 12:35 | 12:35 | 12:35 | 12:35 |
| Mission Type | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling |
| Highest Intensity Survey (mR/h) | 85 | 46 | 70 | 100 | 70 | 50 | 100 | 80 |
| Lowest Intensity Survey (mR/h) | 13 | 11 | 17 | 14 | 8 | 8 | 11 | 12 |
| Average Intensity Survey (mR/h) | 29 | 27 | 39 | 41 | 30 | 24 | 32 | 34 |
| Median Intensity Survey (mR/h) | 24 | 25 | 35 | 33 | 24 | 20 | 29 | 30 |
| Total Integrated Dose | 2.2 | 1.75 | 1.8 | 1.2 | 1.2 | 0.53 | 0.65 | 0.45 |
| No. of Pass | 1 | 2 | 4 | 3 | 5 | 2 | 4 | 1 |
| Time entered cloud | 13:42 | 14:10 | 14:45 | 16:00 | 15:50 | 17:07 | 17:30 | 18:22 |
| Total Time in Cloud (min) | 1.17 | 3.42 | 7.73 | 8.00 | 8.92 | 2.42 | 3.67 | 0.00 |
| Time Exited Cloud | 13:43:10 | 14:13:25 | 14:52:44 | 16:08:00 | 15:58:55 | 17:09:25 | 17:33:40 | 18:22:00 |
| Total Time in Cloud | 0:01:10 | 0:03:25 | 0:07:44 | 0:08:00 | 0:08:55 | 0:02:25 | 0:03:40 | 0:00:00 |
| Median Elapsed Time in Cloud | 00:00:35 | 00:01:42 | 00:03:52 | 00:04:00 | 00:04:28 | 00:01:12 | 00:01:50 | 00:00:00 |
| Median Time in Cloud | 13:42:35 | 14:11:42 | 14:48:52 | 16:04:00 | 15:54:28 | 17:08:12 | 17:31:50 | 18:22:00 |
| Time Elapsed from DT to Median Time in Cloud | 01:07:35 | 01:36:42 | 02:13:52 | 03:29:00 | 03:19:28 | 04:33:12 | 04:56:50 | 05:47:00 |
| Mean time after detonation present in Cloud (hrs) | 1.12 | 1.60 | 2.22 | 3.48 | 3.32 | 4.55 | 4.93 | 5.78 |
| Decay Corrected Contamination (Normalized to Mean Collection Time) | 5558.2 | 2760.9 | 2670.6 | 2005.7 | 1432.7 | 629.3 | 1084.6 | 730.5 |
| Date of survey | 22-Apr-53 | 21-Apr-53 | 21-Apr-53 | 22-Apr-53 | 22-Apr-53 | 21-Apr-53 | 22-Apr-53 | 21-Apr-53 |
| Survey Time (GMT) | 21:15 | 21:15 | 22:50 | 20:45 | 16:50 | 21:10 | 17:25 | 23:15 |
| Time after detonation (hrs) | 104.67 | 80.67 | 82.25 | 106.67 | 100.25 | 80.58 | 100.83 | 82.67 |
| Survey Locations | | | | | | | | |
| Air intake (6 in. inside) | 22 | 17 | 19 | 14 | 14 | 12 | 14 | 15 |
| Right Inner landing gear door | 24 | 24 | 42 | 33 | 24 | 20 | 29 | 30 |
| Right wing (leading edge) | 41 | 36 | 49 | 41 | 32 | 26 | 37 | 41 |
| Right wing tip | 19 | 42 | 24 | 23 | 11 | 16 | 17 | 23 |
| Right wing tip tank | 14 | 11 | 18 | 15 | 8 | 8 | 11 | 16 |
| Right side turbine | 29 | 36 | 70 | 80 | 50 | 42 | 48 | 60 |
| Right horizontal stabilizer | 25 | 24 | 32 | 27 | 20 | 19 | 20 | 25 |
| Tail pipe (6 in. inside) | 22 | 28 | 45 | 44 | 60 | 30 | 38 | 35 |
| Left horizontal stabilizer | 24 | 22 | 32 | 26 | 20 | 18 | 22 | 25 |
| Left side turbine | 29 | 37 | 65 | 70 | 60 | 50 | 55 | 80 |
| Left wing tip tank | 13 | 11 | 17 | 14 | 8 | 10 | 11 | 12 |
| Left wing tip | 19 | 17 | 24 | 25 | 12 | 18 | 13 | 19 |
| Left wing (leading edge) | 43 | 36 | 49 | 100 | 30 | 28 | 35 | 38 |
| Left Inner landing gear door | 24 | 25 | 35 | 41 | 27 | 25 | 37 | 30 |
| Dive brake | 85 | 46 | 60 | 65 | 70 | 42 | 100 | 60 |

| Test Name | Simon | Simon | Simon | Simon | Simon | Simon | Simon | Simon | Simon | Simon |
|---|---|---|---|---|---|---|---|---|---|---|
| Aircraft Code | Tiger Red 1 | Tiger Red 3 | Tiger Red 4 | Tiger White 2 | Tiger White 3 | Tiger White 4 | Tiger Blue 1 | Tiger Blue 2 | Tiger Blue 4 | Cat 1 |
| Aircraft Tail # | 51-1028-A | 51-1037-A | 51-1049-A | 51-1043-A | 51-1045-A | 51-1038-A | 51-1051-A | 51-1054-A | 51-1046-A | 10-1042-A |
| Aircraft Type | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 | F-84 |
| Date | 25-Apr-53 | 25-Apr-53 | 25-Apr-53 | 25-Apr-53 | 25-Apr-53 | 25-Apr-53 | 25-Apr-53 | 25-Apr-53 | 25-Apr-53 | 25-Apr-53 |
| Detonation time (GMT) | 12:30 | 12:30 | 12:30 | 12:30 | 12:30 | 12:30 | 12:30 | 12:30 | 12:30 | 12:30 |
| Mission Type | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling | Sampling |
| Highest Intensity Survey (mR/h) | 110 | 240 | 160 | 60 | 175 | 100 | 210 | 46 | 30 | 80 |
| Lowest Intensity Survey (mR/h) | 30 | 60 | 65 | 13 | 55 | 19 | 42 | 12 | 7 | 9 |
| Average Intensity Survey (mR/h) | 67 | 139 | 112 | 33 | 111 | 54 | 107 | 28 | 16 | 33 |
| Median Intensity Survey (mR/h) | 60 | 120 | 105 | 29 | 105 | 44 | 100 | 26 | 13 | 25 |
| Total Integrated Dose | 1.8 | 1.09 | 1.62 | 1.55 | 1.65 | 1 | 1.5 | 1.55 | 0.66 | 0.26 |
| No. of Pass | 4 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 3 | 1 |
| Time entered cloud | 14:11 | 17:20 | 14:53 | 16:15 | 16:53 | 17:25 | 16:33 | 14:18 | 15:48 | 18:10 |
| Total Time in Cloud (min) | 11.55 | 0.00 | 11.58 | 30.83 | 27.92 | 0.92 | 12.58 | 10.33 | 0.00 | 1.08 |
| Time Exited Cloud | 14:22:33 | 17:20:00 | 15:04:35 | 16:45:50 | 17:20:55 | 17:25:55 | 16:45:35 | 14:28:20 | 15:48:00 | 18:11:05 |
| Total Time in Cloud | 0:11:33 | 0:00:00 | 0:11:35 | 0:30:50 | 0:27:55 | 0:00:55 | 0:12:35 | 0:10:20 | 0:00:00 | 0:01:05 |
| Median Elapsed Time in Cloud | 00:05:46 | 00:00:00 | 00:05:47 | 00:15:25 | 00:13:57 | 00:00:28 | 00:06:17 | 00:05:10 | 00:00:00 | 00:00:33 |
| Median Time in Cloud | 14:16:46 | 17:20:00 | 14:58:47 | 16:30:25 | 17:06:57 | 17:25:28 | 16:39:17 | 14:23:10 | 15:48:00 | 18:10:33 |
| Time Elapsed from DT to Median Time in Cloud | 01:46:46 | 04:50:00 | 02:28:47 | 04:00:25 | 04:36:57 | 04:55:28 | 04:09:17 | 01:53:10 | 03:18:00 | 05:40:33 |
| Mean time after detonation present in Cloud (hrs) | 1.77 | 4.83 | 2.47 | 4.00 | 4.60 | 4.92 | 4.15 | 1.88 | 3.30 | 5.67 |
| Decay Corrected Contamination (Normalized to Mean Collection Time) | 4508.9 | 2854.5 | 5380.1 | 791.5 | 3497.4 | 963.7 | 2849.8 | 2021.4 | 439.1 | 445.3 |
| Date of survey | 27-Apr-53 | 27-Apr-53 | 27-Apr-53 | 27-Apr-53 | 28-Apr-53 | 27-Apr-53 | 27-Apr-53 | 27-Apr-53 | 27-Apr-53 | 27-Apr-53 |
| Survey Time (GMT) | 17:15 | 20:15 | 18:10 | 15:25 | 13:55 | 16:55 | 20:10 | 23:15 | 14:30 | 15:00 |
| Time after detonation (hrs) | 64.75 | 67.75 | 65.67 | 62.92 | 85.42 | 64.42 | 67.67 | 70.75 | 62 | 62.5 |
| Survey Locations | | | | | | | | | | |
| Air intake (6 in. inside) | 30 | 80 | 75 | 25 | 110 | 31 | 85 | 17 | 15 | 11 |
| Right Inner landing gear door | 60 | 110 | 100 | 30 | 100 | 41 | 100 | 26 | 11 | 21 |
| Right wing (leading edge) | 85 | 180 | 160 | 46 | 160 | 65 | 110 | 38 | 20 | 36 |
| Right wing tip | 48 | 95 | 95 | 21 | 90 | 26 | 80 | 20 | 11 | 20 |
| Right wing tip tank | 32 | 80 | 70 | 13 | 55 | 21 | 42 | 12 | 7 | 13 |
| Right side turbine | 110 | 240 | 130 | 60 | 135 | 100 | 160 | 42 | 27 | 80 |
| Right horizontal stabilizer | 58 | 120 | 120 | 27 | 110 | 44 | 100 | 25 | 13 | 24 |
| Tail pipe (6 in. inside) | 70 | 140 | 105 | 43 | 95 | 80 | 100 | 29 | 17 | 46 |
| Left horizontal stabilizer | 55 | 120 | 115 | 29 | 105 | 41 | 100 | 24 | 13 | 25 |
| Left side turbine | 90 | 240 | 125 | 48 | 140 | 100 | 140 | 41 | 30 | 80 |
| Left wing tip tank | 31 | 60 | 65 | 13 | 55 | 19 | 60 | 16 | 7 | 9 |
| Left wing tip | 49 | 105 | 100 | 21 | 80 | 35 | 70 | 20 | 10 | 18 |
| Left wing (leading edge) | 90 | 170 | 160 | 39 | 150 | 65 | 160 | 36 | 20 | 38 |
| Left Inner landing gear door | 80 | 120 | 105 | 29 | 100 | 50 | 90 | 26 | 11 | 29 |
| Dive brake | 110 | 220 | 160 | 44 | 175 | 90 | 210 | 46 | 22 | 44 |