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COST AND EFFECTIVENESS OF DECONTAMINATION PROCEDURES FOR LAND TARGETS

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by

J. D. Sartor
H. B. Curtis
H. Lee
W. L. Owen

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U. S. NAVAL RADIOLOGICAL DEFENSE LABORATORY
San Francisco 24, California

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ABSTRACT

The cost and effectiveness of basic radiological decontamination procedures for land target components were investigated at a field test conducted at Camp Stoneman in September 1956. Synthetic fallout was developed to provide contaminants simulating two types of radioactive debris, and two contaminating events were considered: (1) a dry fallout from a low-yield (kiloton) land burst, or a high-yield (megaton) land or shallow-water burst, and (2) a wet slurry fallout from a low-yield shallow-water burst. Areas contaminated at dose rates of 1,000 r/hr and 10,000 r/hr at 1 hour after burst were hypothesized to be situations of greatest interest and their dose rates were simulated according to the mass-radiation relationship of 25 mg/sq ft/r/hr at 1 hour.

The five procedures evaluated were combinations of the following basic methods: firehosing, hand scrubbing with and without detergent, motorized flushing and motorized scrubbing with and without detergent.

Decontamination was tested on portland cement concrete and asphaltic concrete pavements; and composition shingle, tar and gravel, roll roofing, wood shingle, and corrugated galvanized steel roofs. The tests are described in detail and the cost and effectiveness of the various procedures are presented. Extrapolation of the data and application to actual situations are discussed.

For similar initial mass levels, slurry contaminant will, in all probability, be more difficult to remove than the dry contaminant.

On paved areas, the motorized flushing procedure ranked lowest in effort expended. The firehosing procedure ranked lowest in effort expended on roofing areas.

The use of synthetic fallout in field operations of the nature and scope of the Camp Stoneman operation is satisfactory.

The decontamination procedures evaluated, with few exceptions, were 95 to 99 percent effective in the removal of the synthetic fallout material from paved areas and building roofs.

A visual record of the study is in the moving picture Land Target Decontamination Tests, Stoneman 1, Registry No. SHIPS 7-57.

SUMMARY

The Problem

To determine the cost and effectiveness of basic decontamination procedures for land target components whose surfaces are subject to radiological contamination from the fallout produced by the detonation of a nuclear weapon. Synthetic contaminants simulated the debris from low- and high-yield weapons detonated at the surface of land (dry fallout) and shallow water (i.e., a harbor; slurry fallout). Common paved and roofing surfaces were tested. Combinations of manual and motorized flushing and scrubbing, with and without detergent, were used.

Findings

With few exceptions, the methods evaluated were 95 to 99 percent effective in the removal of the contaminant from the paved and roofing test areas.

The motorized flushing procedure required the least effort in achieving the reported effectiveness for paved areas and the firehosing procedure ranked lowest in effort expended on roofing areas.

Costs were arrived at which are not considered as necessarily optimum. The synthetic fallout, developed to provide the contaminant, was satisfactory and is recommended for use in field operations of the nature and scope of this series of tests.

ADMINISTRATIVE INFORMATION

This investigation was sponsored by the Bureau of Yards and Docks under Sub-project NY 320-001-9, Technical Objective AW-5c. The study also is part of the technical program for the Department of the Army established between Department of Army, Office, Chief of Research and Development, and the Bureau of Ships (joint agreement, 23 November 1956).

The work is described, as Program 6, Problem 3, in this laboratory's Preliminary Presentation of USNRDL Technical Program For FY 1957, February 1956.

To provide a visual record, the investigation was filmed. The moving picture Land Target Decontamination Tests, Stoneman 1, Registry No. SHIPS 7-57, will be completed.

ACKNOWLEDGEMENTS

The Camp Stoneman project could not have been fulfilled without the wholehearted assistance and cooperation of many organizations and the personnel therefrom. The performance of the 50th Chemical Service Platoon, U. S. Army, assigned to support the test, was outstanding in every respect. In addition, the authors wish to acknowledge the invaluable aid received from the following organizations: Headquarters, Sixth Army, Presidio, San Francisco, California; Post Engineer, Camp Stoneman, California; Research Directorate, Air Force Special Weapons Center, Kirtland Air Force Base, New Mexico; Mobile Construction Battalion Five, Civil Engineer Corps, U. S. Navy, Port Hueneme, California; Phillips Petroleum Co., Atomic Energy Division, Materials Testing Reactor, Arco, Idaho; South Pacific Division Laboratories, Corps of Engineers, U. S. Army, Sausalito, California.

The assistance of Major William Home, USA, and LTJG William Glover, USNR, played an important part in the successful completion of the operation. The advice and assistance rendered by Miss Marion Sandomire, Statistical Consultant to the Scientific Department of this laboratory, were invaluable during the evaluation of the data. The editorial assistance of Mr. M. B. Wiener in the final preparation of the report is also acknowledged.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND AND HISTORY

There is a general lack of accurate data applicable to the radiological recovery of land targets. In the most up-to-date generally available source, the manual Radiological Recovery of Fixed Military Installations, NAVDOCKS TP-PL-13, August 1953,[1] the values for cost and effectiveness of basic decontamination procedures were compiled in certain cases from inadequate data and best estimates.

This investigation was undertaken to obtain additional data in order to provide reliable decontamination values and also to obtain a statistically significant estimate of the experimental error.

Previous studies in the recovery of components of land targets have been conducted on a limited basis.

Decontamination studies were conducted on model buildings and paved areas at Operation JANGLE.[2] The data gathered by the different participating groups were difficult to correlate due to variances in operating techniques and lack of uniformity in methods of radiation measurements. Difficulty in obtaining contaminated test surfaces and unpredictability of weather conditions (two ever-present variables in nuclear weapon tests) also limited the significance and validity of the results to a great extent.

Limited data were obtained from a field test conducted at the U. S. Naval Advance Base Personnel Depot, San Bruno, California.[3] Liquid and slurry contaminants used at that time have been replaced by more realistic synthetic fallout formulated on the basis of data from laboratory research and nuclear weapon tests.

Tests also have been conducted at the Army Chemical Center[4] to determine the effectiveness of gross decontamination techniques for radiological warfare (RW) contaminant on asphaltic concrete road surfaces. However, the physical properties of the radioactive contaminants used for these tests limit the applicability of these data to problems associated with fallout from nuclear detonations.

Other laboratory experiments[5,6] have been conducted with liquid contaminants to determine the decontamination reactions on various materials. The data obtained from these experiments can be extrapolated to large areas to determine effectiveness of decontamination but cost of decontamination of large areas cannot be determined by such extrapolations.

1.2 OBJECTIVES

The principal objectives of this investigation were:

a. To determine the effectiveness of combinations of basic decontamination methods applied to paved and roof surfaces contaminated with dry or slurry type fallout material.

b. To determine the cost of the basic decontamination procedures in terms of labor and equipment requirements.

c. To recommend, from the results obtained in a and b, procedures for the recovery of land target components.

d. To evaluate the use of synthetic fallout material as a simulant of radioactive fallout from megaton (MT) and kiloton (KT) weapons detonated over land and harbors.

1.3 SCOPE OF TEST

The tests centered around the evaluation of five decontamination procedures applied to seven different surfaces. The five procedures evaluated were combinations of the basic methods of firehosing, hand scrubbing with and without detergent, motor flushing, and motor scrubbing with and without detergent. The surfaces contaminated consisted of: paved areas of portland cement concrete and asphaltic concrete; and roofing areas composed of tar and gravel, composition shingles, wood shingles, asphalt roll roofing and corrugated galvanized metal.

Two contaminating conditions were considered: a dry fallout material resulting from a low-yield (KT) land burst, or a high-yield (MT) land or shallow water surface burst; and a slurry material representing a low-yield (KT) shallow water surface burst. Two dose rates which could be anticipated under the given conditions were simulated for each type of contaminant: 1,000 r/hr and 10,000 r/hr both at 1 hour after burst. The radiation levels were simulated according to the mass-radiation relationship of 25 mg/sq ft/r/hr at 1 hour.[7]

1.4 SELECTION OF TEST SITE

Camp Stoneman, a deactivated Army Camp near Pittsburg, California, was selected as the test site. Appendix A relates the basis for selection and describes the test site and the pre-test preparations. Appendix B describes the test surfaces.

1.5 TEST LIMITATIONS

The test surfaces available at the test site imposed certain restrictions upon the test data. Such factors as surface condition (cracks, form lines, etc.), weathering of surfaces, degree of slope of test areas, and types of surface material were noted but no attempt was made to alter the existing conditions except for the clearing of weeds and foreign materials from the test areas. Test panels, representing roofing materials not available at the test site, were fabricated.

CHAPTER 2

TEST PROCEDURES

2.1 PRODUCTION OF SYNTHETIC FALLOUT MATERIAL

The design and preparation of the synthetic fallout material will be described in complete detail in a forthcoming report.[8] For the sake of completeness, a brief resume of the general procedures and techniques used during the operation follows. The synthetic fallout consisted of a radioactive isotope and a bulk carrier, and was used in two forms, dry and slurry.

2.1.1 Selection of Radioisotope

The radionuclide La^{140} was chosen as the radioactive tracer in the synthetic fallout material, because it:

a. is a trivalent ion and therefore readily adsorbed on the bulk carrier particles. Preliminary experiments[9] had been performed, prior to this field test, on the adsorption of La^{140} on the carrier material later selected. These experiments demonstrated that trivalent La^{140} was strongly adsorbed to these carrier materials and would not desorb under the planned decontamination conditions. These characteristics simulate the behavior of fallout samples[10] from land surface and land subsurface nuclear detonations, whose radioactive elements were quite insoluble.

b. has a 40.2-hr half-life. Natural decay would reduce the radioactivity at the test site to negligible amounts within a short time after the completion of the tests.

c. has an average gamma energy of 1.2 Mev, readily measured by the detection instruments used.

d. is easily produced by the La^{139} (n, γ) La^{140} reaction in a high thermal-neutron flux obtainable in a nuclear reactor.

2.1.2 Selection of Bulk Carrier Material

The criteria for selecting the bulk carrier materials were: that for a land burst should consist of typical soil from the target complex and that for a harbor burst should consist of the harbor bottom material and seawater.

Accordingly Ambrose clay loam from the Camp Stoneman site was used in the dry contaminant and harbor bottom material from the San Francisco Bay was used in the slurry contaminant.

To obtain acceptable physical properties of the bulk carrier material and for ease in dispersing and handling later on, the required amounts of soil and harbor bottom material were taken to the South Pacific Division Laboratory,* Corps of Engineers, U. S. Army, Sausalito, California, for shredding, drying, crushing and screening. All material passing a 30-mesh screen was acceptable. The range and distribution of the bulk carrier particle sizes is considered typical of actual fallout from a detonation affecting similar soils.

2.1.3 Preparation of Synthetic Fallout

The facilities at the Materials Testing Reactor, Arco, Idaho, were used to produce the La^{140}. Two grams of La_2O_3 were encapsulated in quartz and bombarded in a flux of 10^{14} n/cm^2/sec for a time sufficient to produce approximately 6 curies of La^{140} on the day it was to be used at Camp Stoneman. To achieve the test schedule, 2 capsules were carried in each of 11 shipments by a U. S. Air Force aircraft from Arco, Idaho, to Travis AFB near Camp Stoneman, California.

The La^{140} was prepared in a solution for mixing with the carrier from behind a concrete-block shielding wall by means of a pair of master-slave manipulators.

The dry fallout simulant was prepared by combining the La^{140} solution and the Ambrose clay loam carrier in the mixing drum of a modified Jaeger 3-1/2 cubic yard transit-mix truck (Fig. 2.1). The lanthanum solution was pumped to a holding bottle on the side of the transit-mix truck and fed to a pneumatic nozzle located in the head end of the rotating drum, where it was atomized. The liquid aerosol was adsorbed uniformly onto the bulk carrier material.

* Petrographic and chemical tests of samples of each material were made by the South Pacific Division Laboratory, and the results are presented in Appendix C.

Fig. 2.1 Transit-mix Truck for Mixing Contaminant.

Fig. 2.2 Crash Trailer for Dispersing Slurry Contaminant on Paved Areas.

For the preparation of the slurry simulant, dried harbor bottom material was mixed with the lanthanum in the transit-mix truck, transferred to a measuring hopper, and thence to the mixing tank of a modified Navy "crash trailer" (Fig. 2.2) where an equal weight of fresh water was mixed with it. The 1:1 ratio of dry harbor bottom soil to fresh water was assumed to be typical of the actual fallout being simulated. The use of salt water was not necessary as the salt residue from the water after drying would not significantly affect the decontamination.

For the entire series of tests, approximately 40,000 lb of dry synthetic fallout and 31,000 lb (wet weight) of slurry synthetic fallout were prepared. A small portion of this total was used for special tests conducted by the U. S. Forest Service and the U. S. Army Quartermaster Corps (see section 2.6).

2.2 DISPERSAL OF SYNTHETIC FALLOUT MATERIAL

The amount of synthetic fallout to be dispersed[8] depended on the radiation levels to be simulated. The dose rates simulated, as indicated in section 1.3, were 1000 r/hr and 10,000 r/hr, both at 1 hr after burst. Thus, according to the mass-radiation relationship of 25 mg/ft^2 per r/hr at 1 hr, the weight of material deposited for 1000 r/hr would be 25 g/ft^2 and for 10,000 r/hr, 250 g/ft^2. To measure the mass actually deposited, 1-ft square pans were placed on the test area prior to dispersing and the amount collected was weighed.

2.2.1 Paved Areas

Dry simulant was dispersed over the paved areas from a modified Burch Hydron Spreader* mounted on the rear of a 2-1/2-cu yd dump truck (Fig. 2.3). An aluminum hopper was installed on the truck to contain the synthetic fallout material and feed it directly into the spreader when the truck bed was raised. To reduce the effects of the wind, a fabricated aluminum extension was installed on the spreader which limited the free fall of the material to the ground to about 2 in. The layer of material simulating 1000 r/hr at 1 hour was approximately 0.008 in. deep and that for 10,000 r/hr, 0.083 in.

Slurry simulant was dispersed on the paved areas from a "crash trailer" (Fig. 2.2).

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*Mfd. by Burch Corp., Crestline, Ohio

Fig. 2.3 Dump Truck for Dispersing Dry Contaminant on Paved Areas.

Fig. 2.4 Hand-drawn Spreader for Dispersing Dry Contaminant on Roof Areas.

2.2.2 Roof Areas

The dry simulant was dispersed over the roof areas and test panels from a hand-drawn spreader (Fig. 2.4). An rpm meter was mounted on the spreader to aid in pulling the spreader at a constant speed.

The slurry material was dispersed over the roof areas and panels from a hand-drawn "caddy cart".

2.3 COST AND EFFECTIVENESS MEASUREMENTS

2.3.1 Cost Measurement

To determine the cost of the various decontamination procedures tested, the factors of manpower, equipment, and supplies were investigated. Observations and records were made on:

a. Manpower requirements - the total number of men required to perform the decontamination procedure, the working time, and the total time which included equipment set-up and dressing in protective clothing and changing back to normal garb.

b. Equipment and material requirements - the types, amounts, and rates of use of equipment and supplies.

2.3.2 Effectiveness Measurement

To determine the effectiveness of the various procedures, measurements were taken of the radiation levels present on the test areas just prior to contamination (background), after contamination, and after decontamination. Measurements were taken at twenty locations on each paved area and at 5 or 8 locations on each roofing area and panel, depending on its size.

Certain of the portland cement concrete areas were considered to be more cracked and broken than normally would be expected. Consequently, all the residual radiation measurements on or near the large cracks were discarded.

Because it was not possible to hold the specific activity of the synthetic fallout constant from day to day, a difference in average radiation levels between test areas did not necessarily reflect a similar difference in the contaminant mass levels. In order to draw comparisons between various tests it was necessary to adjust the readings to a common specific activity equal to unity. This was accomplished by dividing the computed average radiation level for a given test area by the known specific activity for that same area.

$$\bar{R}_m = \frac{\bar{R}_r}{\bar{a}} \qquad (2.1)$$

where $\bar{R}_m$ = the average amount of contaminant remaining, in mass/unit area, after decontamination,
$\bar{R}_r$ = the average final radiation measurement less background, in counts/unit time/unit area, adjusted for decay to the time of the initial readings,
$\bar{a}$ = the average specific activity of the applicable contaminant, in counts/unit time/gram.

The same technique was used to compute values of $\bar{I}_m$ (mass levels initially present) from measurements of $\bar{I}_r$ (initial radiation levels).

The variability of $\bar{R}_m$ was determined for the tests on paved areas from the variation of $\bar{R}_r$ and $\bar{a}$ by a standard statistical technique. There were insufficient data from the tests on the roofing materials for the statistical treatment.

It should be noted that values for $\bar{R}_m$ and $\bar{I}_m$ are not absolute, since their units are given only in a relative sense as mass per unit area. These values may be thought of as being proportional to grams per square foot. However, the factor of proportionality which could permit the use of these units is indeterminate, because the geometries and efficiencies of both the monitoring and specific activity determination instruments are not well enough defined.

Inasmuch as this factor is a constant, the relative positions between the values assigned to $\bar{R}_m$ or $\bar{I}_m$ will not shift. Thus, it is not imperative that this proportionality factor or the absolute magnitudes of the mass levels be established.

The amount of contaminant remaining, $\bar{R}_m$, as computed from Eq 2.1, is used throughout this report as the basic measure of decontamination effectiveness. This choice was permissible on the assumption that the amount of tracer activity adsorbed on each particle of bulk carrier material was proportional to the mass of the particle.

A secondary but sometimes useful expression, the percent fraction remaining, is also presented as an indication of decontamination effectiveness.

$$\bar{F} = 100 \times \frac{\bar{R}_r}{\bar{I}_r} \qquad (2.2)$$

where $\overline{F}$ = the average fraction remaining in percent,
$\overline{I}_r$ = the average initial radiation measurement in counts/unit time/unit area,
$\overline{R}_r$ = the average final radiation measurement, in counts/unit time/unit area, less background and adjusted for decay to the time $\overline{I}_r$ was measured.

No correction for specific activity is required here since a ratio of two measurements having equal specific activities is involved. The relative merits of $\overline{F}$ versus $\overline{R}_m$ are discussed in section 4.1.

The following instruments were used:

A shielded gamma instrument (Fig. 2.5) was used on paved areas to measure gamma radiation from a 3-ft diameter area directly below the detector. The electronic portion of the instrument was essentially the same as that of the wide-range gamma-sensitive liquid flow monitor,[11] consisting of a 1-in. square NaI crystal, a photomultiplier-tube probe, a preamplifier, a log rate meter, and a Brown recorder, all connected in series. Power was supplied by a 5-HP 110-120-V AC motor-generator. The lead shield into which the detector was inserted was mounted upon a four-wheel trailer. The Brown recorder and the log rate meter were mounted in a jeep which was used to pull the trailer.

An unshielded gamma detector (Fig. 2.6) was used to measure the unattenuated gamma radiation field from a height of 1 foot on roofing areas. The electronic system was the same as that described above.

An AN/PDR-27F radiac was used to train the supporting Army personnel in methods of field monitoring.

The first two instruments were calibrated with standard Co^{60} point sources and a 5-ft diameter area of plywood contaminated with La^{140}. The latter calibration technique consisted of placing the detector probes in a fixed position for several days and comparing the recorded decay with the known decay. The calibration showed that the instrument responses were linear over the entire range of the log rate meter.

The third radiac was calibrated only on a standard Co^{60} point source. Daily calibration checks were made on all instruments in the field.

2.4 DECONTAMINATION PROCEDURES

2.4.1 Paved Areas

The basic decontamination procedures evaluated on paved areas, as stated in section 1.2, were:

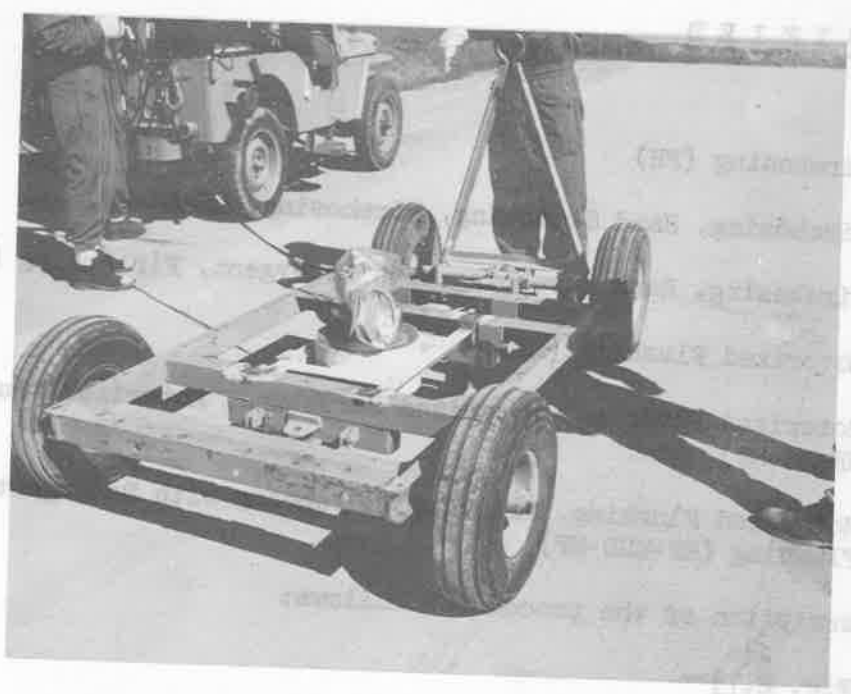

Fig. 2.5 Shielded Gamma Detector for Measuring Radiation Levels on Paved Areas.

Fig. 2.6 Unshielded Gamma Detector for Measuring Radiation Levels on Roofing Areas.

a. Firehosing (FH)

b. Firehosing, Hand Scrubbing, Firehosing (FH-HS-FH)

c. Firehosing, Hand Scrubbing with Detergent, Firehosing (FH-HSD-FH)

d. Motorized Flushing (MF)

e. Motorized Flushing, Motorized Scrubbing, Motorized Flushing MF-MS-MF)

f. Motorized Flushing, Motorized Scrubbing with Detergent, Motorized Flushing (MF-MSD-MF)

A description of the procedures follows:

FH (Fig. 2.7)

Equipment: A standard 2-1/2-in. firehose running from a nearby fire hydrant to the test area where it fed two 1-1/2-in. firehoses; a 500-gpm portable pump inserted in the hose line near the hydrant to maintain a constant nozzle discharge pressure of 80 psig for all of the tests; a standard 1-1/2-in. playpipe with 5/8-in. nozzle orifice attached to each firehose.

Personnel: 6 to 8 men:

1 Supervisor
1 Pump Operator
2 or 3 Hose Tenders
2 or 3 Nozzle Men

Procedure: Starting at the higher end of the slope and proceeding down the length of the test area, the nozzle men advanced side by side pushing the contaminant ahead and to each side. The rate of advance was determined visually, the work progressing as fast as the surface appeared to be cleaned.

FH-HS-FH (Fig. 2.8)

Equipment: The same as for FH, plus 4 to 6 long-handled scrub brushes.

Personnel: 10 to 14 men:

1 Supervisor
1 Pump Operator
2 or 3 Hose Tenders
2 or 3 Nozzle Men
4 to 6 Scrubbers

Fig. 2.7 Firehosing Paved Area.

Fig. 2.8 Firehosing and Hand Scrubbing Paved Area.

Procedure: The hose team started at the higher end of the area and worked toward the low, proceeding at a rate somewhat faster than the rate used for the FH procedure, as the purpose was to prewet the surface and remove the bulk of the contaminant.

When the hosing team had progressed a sufficient distance, and while the area was still wet, the scrubbing team began, using short, brisk strokes until the area was thoroughly brushed.

When the scrubbers had advanced approximately 50 ft, the hosing group returned to the starting point and commenced the final hosing. This last hosing was accomplished thoroughly at a rate comparable to that employed for the FH procedure. The scrubbers stepped aside as they were overtaken by the hose team, which continued into the next section of the test area, to perpetuate the cycle.

FH-HSD-FH

Equipment: The FH-HS-FH equipment plus the detergent (ORVUS*) and a bucket for hand-casting it.

Personnel: The same as for FH-HS-FH plus one man for spreading detergent, 11 to 15 men.

Procedure: The detergent spreader followed the initial hosing quite closely, hand-casting the detergent powder. In other respects, the procedure was the same as that used for FH-HS-FH.

MF (Fig. 2.9)

Equipment: A street-flusher truck of 3000-gal capacity and with a 500-gpm pump and two forward and one side discharge nozzles.

Personnel: A driver and one supervisor.

Procedure: The truck was driven at approximately 5 mph, down the slope of the long dimension of the test area, the first pass being made along the high side of the cross slope. Successive adjacent passes were made over the full width of the area. The nozzles were directed to take advantage of the longitudinal as well as the cross slope. Usually, 3 to 4 passes were sufficient to clean the 20-ft wide test strips.

MF-MS-MF (Fig. 2.10)

Equipment: The street flusher and a Wayne Street Sweeper, Model 1-450.

*Industrial form of TIDE, manufactured by Proctor and Gamble Mfg. Co.

Fig. 2.9 Motorized Flushing Roadway

Fig. 2.10 Motorized Scrubbing Roadway

Personnel: A driver for each of the two vehicles and one supervisor.

Procedure: Sufficient passes were made with the flusher to wet the test area. The test strip was then swept as clean as possible with the sweeper, as many as 8 passes being required. A second flushing next was applied as in the flushing procedure used alone. Both vehicles were driven at speeds less than 5 mph.

MF-MSD-MF

Equipment: The MF-MS-MF equipment plus the detergent and a bucket for hand-casting.

Personnel: A driver for each of the two vehicles, one man for hand-casting the detergent, and one supervisor.

Procedure: After the first cursory flushing, the detergent was hand-cast over the test area. Thereafter, the procedure was identical with the MF-MS-MF operation.

2.4.2 Roofing Areas

The basic decontamination procedures evaluated on roofing areas were:

a. Firehosing (FH)

b. Firehosing, Hand Scrubbing, Firehosing (FH-HS-FH)

c. Firehosing, Hand Scrubbing with Detergent, Firehosing (FH-HSD-FH)

A description of the procedures follows:

FH (Fig. 2.11)

Equipment: The same as for firehosing paved areas except for only one 1-1/2-in. firehose equipped with a Model #4 NAP Griswold Fog Nozzle. The pump was adjusted, in this case, to deliver 60 psig at the nozzle. Ladders or scaffolds for access to the roofing areas on existing buildings were required.

Personnel: The number varied, but generally 1 man tended the pump, 1 or 2 handled the hose, 2 directed the 1-1/2-in. nozzle, and at least 1 supervised.

Fig. 2.11 Firehosing Roof Area.

Fig. 2.12 Firehosing and Hand Scrubbing Roof Area.

Procedure: Hosing was started at the peak of the roof area or panel, and proceeded across and down to the edge of the area. The nozzle operators experienced no great difficulty in working on the roof areas.

On the tar and gravel areas, which were essentially flat, the firehosing started at the edge of the roof and the hosers walked backward toward the center while aiming the nozzle toward the roof's edge. This kept the loosened gravel from becoming windrowed and blocking the water runoff. The rate of advance was determined visually, the work progressing as fast as the area appeared to be cleaned.

FH-HS-FH (Fig. 2.12)

Equipment: The FH equipment as before plus 4 long-handled scrub brushes.

Personnel: One man tended the pump, 1 to 2 the hose, and 2 the nozzle; 3 to 4 men scrubbed and at least 1 supervised.

Procedure: On the first pass, the firehose team operated as before but at a faster rate. Then the area was scrubbed until it looked clean. The second, clean-up firehosing was at the same rate as for the FH procedure.

FH-HSD-FH (Fig. 2.13)

Equipment: The FH-HS-FH equipment plus a small bucket for hand-casting the detergent.

Personnel: Those for FH-HS-FH plus 1 man for dispersing the detergent.

Procedure: The procedure was the same as for FH-HS-FH except that the detergent was applied to the surface immediately after the initial firehosing.

2.5 RADIOLOGICAL SAFETY

Radiological-safety monitors were present during the preparation and dispersal of the synthetic fallout material and during decontamination. A rad-safe courier accompanied each shipment of La^{140} from Arco, Idaho, to Camp Stoneman. Complete details of the rad-safe support are described in Reference 12.

Fig. 2.13 Hand Scrubbing, With Detergent, Roof Area

2.6 PARTICIPATION BY OTHER AGENCIES

The California Forest and Range Experimental Station, U. S. Forest Service, Berkeley, Calif., and the Quartermaster Research and Development Center, Natick, Mass., conducted experiments during the operation. Their interest primarily was to take advantage of the availability of synthetic fallout, technical monitoring, and rad-safe facilities.

The California Forest and Range Experimental Station conducted preliminary experiments on the decontamination of overgrown land areas by burning. A report[13] has been issued on this phase of the operation.

The Quartermaster Research and Development Center conducted experiments to determine the extent of contamination of field food-preparation equipment, food distribution equipment, and eating utensils, and to attempt various methods of decontamination.

CHAPTER 3

RESULTS

3.1 DECONTAMINATION OF PAVED AREAS

The results of decontaminating paved areas are shown in Table 3.1 for portland cement concrete and Table 3.2 for asphaltic concrete.

The area numbers (first column) correspond with those in Fig. A.1 of Appendix A. The values $\bar{I}_m$ and $\bar{R}_m$ are proportional to the mass of deposited synthetic fallout material per unit area, the average shielded gamma detector readings having been divided by the average specific activity of the simulant used in each case (Eq 2.1). Ninety-five percent confidence limits of the $\bar{R}_m$ value for each of the tests are listed, i.e., intervals in which $\bar{R}_m$ would be expected to fall 95 percent of the time if the test were repeated under similar conditions. Also presented is the average fraction of the initial radiation field remaining, $\bar{F}$, for each test (Eq 2.2).

3.2 DECONTAMINATION OF ROOFING MATERIALS

The results of decontaminating the various roofing materials are shown in Tables 3.3 through 3.7.

The area numbers (first column) refer to those in Fig. A.1. The initial and final measurements $\bar{I}_m$ and $\bar{R}_m$ are the result of radiation readings taken with the unshielded gamma detector divided by the specific activity of the synthetic fallout used in each case (Eq 2.1). Only the most centrally located monitoring stations on each roof test area were used for the reasons discussed in Chapter 4.

3.3 COSTS OF DECONTAMINATION PROCEDURES

The costs of the decontamination procedures are presented in Table 3.8 for paved areas and Table 3.9 for the roofing materials.

TABLE 3.1 DECONTAMINATION RESULTS FOR PORTLAND CEMENT CONCRETE

Area No.	Decontamination Procedure	Type of Contaminant	Planned Initial Surface Density (1) (g/sq ft)	Results: Relative Values $\bar{I}_m$ (mass/unit area)	Results: Relative Values $\bar{R}_m$ (mass/unit area)	95% conf. limits on $\bar{R}_m$ lower	95% conf. limits on $\bar{R}_m$ upper	$\bar{F}$ (%)
D-9	FH	Dry	250	8520	27.3	14.1	40.5	0.32
D-3	FH-HS-FH	Dry	250	8960	19.5	16.1	22.9	0.22
E-2	FH-HSD-FH	Dry	250	8440	36.0	25.8	46.2	0.43
C-4	MF	Dry	250	7530	32.1	8.30	55.9	0.43
C-3	FH	Dry	25	2420	26.9	19.3	34.5	1.1
D-8	FH-HS-FH	Dry	25	1300	9.00	6.80	11.2	0.69
A-1	MF-MS-MF	Dry	25	1340	9.81	6.81	12.8	0.73
C-2	FH	Slurry	125	3420	35.7	24.3	47.1	1.0
D-5	FH-HSD-FH	Slurry	125	3060	26.3	24.1	30.5	0.86
D-4	MF	Slurry	125	5350	56.3	51.7	60.9	1.1
E-1	MF-MSD-MF	Slurry	125	4390	68.0	61.4	74.6	1.5
D-7	FH	Slurry	12.5	1250	45.8	36.8	54.8	3.7
A-2	FH-HS-FH	Slurry	12.5	736	13.7	9.50	17.9	1.9
D-2	FH-HSD-FH	Slurry	12.5	1920	35.4	21.2	49.6	1.8
B-1	MF	Slurry	12.5	1250	43.6	35.2	52.0	3.5
C-5	MF-MS-MF	Slurry	12.5	650	29.0	23.6	34.4	4.5
A-1	MS (2)	Dry	250	9820	1020.	790.	1350.	10.
D-7	Decon. Truck (2)	Slurry	12.5	1830	30.1	26.1	34.1	1.6

(1) Slurry surface densities are on a dry weight basis.

(2) Not part of the test as planned but included later (see section 4.1.1.6).

TABLE 3.2 DECONTAMINATION RESULTS FOR ASPHALTIC CONCRETE

Area No.	Decontamination Procedure	Type of Contaminant	Planned Initial Surface Density (g/sq ft)[1]	Results: Relative Values $\overline{I}_m$ (mass/unit area)	Results: Relative Values $\overline{R}_m$ (mass/unit area)	95% conf. limits on $\overline{R}_m$: lower	95% conf. limits on $\overline{R}_m$: upper	$\overline{F}$ (%)
H-1	FH	Dry	250	7290	70.6	58.0	83.2	0.97
G-3	FH-HS-FH	Dry	250	7170	61.0	53.2	68.8	0.85
F-11	MF	Dry	250	5510	37.9	28.3	47.5	0.69
H-3	MF-MS-MF	Dry	250	11000	59.6	52.8	66.4	0.70
F-12	MF-MSD-MF	Dry	250	9120	36.0	27.2	44.8	0.39
G-1	FH	Dry	25	1890	49.4	0.80	98.0	2.6
G-4	FH-HS-FH	Dry	25	1790	21.9	18.5	25.3	1.2
H-4	FH-HSD-FH	Dry	25	1400	12.2	7.60	16.8	0.87
F-8	MF	Dry	25	1190	12.6	9.20	16.4	1.0
F-3	FH	Slurry	125	4020	66.9	58.1	75.7	1.6
H-2	FH-HS-FH	Slurry	125	3420	39.6	36.6	42.6	1.2
F-7	MF	Slurry	125	4470	52.5	49.1	55.9	1.2
F-9	MF-MS-MF	Slurry	125	3980	52.9	49.9	55.9	1.3
F-6	FH	Slurry	12.5	1800	51.7	31.9	71.5	2.8
F-4	FH-HS-FH	Slurry	12.5	933	37.3	34.1	40.5	4.0
F-10	FH-HSD-FH	Slurry	12.5	720	5.84	4.44	7.24	0.81
F-2	MF	Slurry	12.5	767	51.5	45.3	57.7	6.7
G-2	MF-MSD-MF	Slurry	12.5	895	18.3	15.9	20.7	2.0
F-5	MS[2]	Dry	250	8890	1137.	1020.	1250.	13.
G-1	Decon Truck[2]	Dry	250	11,100	163.	146.	180.	1.5

(1) Slurry surface densities are on a dry weight basis.

(2) Not part of the test as planned but included later (see section 4.1.1.6).

TABLE 3.3 DECONTAMINATION RESULTS FOR TAR AND GRAVEL ROOF AREAS

TG Area No.	Decontamination Procedure	Type of Contaminant	Planned[1] Initial Surface Density (g/sq ft)	Relative Values: $\bar{I}_m$ (mass/unit area)	Relative Values: $\bar{R}_m$ (mass/unit area)	$\bar{F}$ (%)
5	FH	Dry	250	187[2]	.57[2]	0.30
2	FH-HS-FH	Dry	250	951	11	1.2
3	FH-HSD-FH	Dry	250	846	11	1.2
6	FH	Dry	25	649	11	1.7
11	FH-HS-FH	Dry	25	466	15	3.2
1	FH-HSD-FH	Dry	25	262	.46	0.18
4	FH	Slurry	125	1120	7.3	0.65
10	FH-HS-FH	Slurry	125	983	8.4	0.85
12	FH-HSD-FH	Slurry	125	1120	3.8	0.34
9	FH	Slurry	12.5	81.7	3.3	4.0
7	FH-HS-FH	Slurry	12.5	87.5	2.9	3.3
8	FH-HSD-FH	Slurry	12.5	91.2	0.25	0.27

(1) Slurry initial surface densities are on a dry weight basis.

(2) Readings with AN/PDR-27F.

TABLE 3.4 DECONTAMINATION RESULTS FOR COMPOSITION SHINGLE ROOF AREAS

CS Area No.	Decontamination Procedure	Type of Contaminant	Planned[1] Initial Surface Density (g/sq ft)	Relative Values $\bar{I}_m$ (mass/unit area)	$\bar{R}_m$ (mass/unit area)	$\bar{F}$ (%)
1	FH	Dry	250	1150	20	1.7
2	FH-HS-FH	Dry	250	1320	31	2.3
3	FH-HSD-FH	Dry	250	919	11	1.2
7	FH	Dry	25	256	14	5.4
8	FH-HS-FH	Dry	25	281	11	3.9
9	FH-HSD-FH	Dry	25	241	8.9	3.7
6	FH	Slurry	125	910	28	3.1
4	FH-HS-FH	Slurry	125	760	25	3.3
5	FH-HSD-FH	Slurry	125	791	27	3.4
11	FH	Slurry	12.5	126	17	14
10	FH-HS-FH	Slurry	12.5	139	13	9.4
12	FH-HSD-FH	Slurry	12.5	79.2	1.2	1.5

(1) Slurry initial surface densities are on a dry weight basis.

TABLE 3.5 DECONTAMINATION RESULTS FOR WOOD SHINGLE ROOFING PANELS

Decontamination Procedure	Type of Contaminant	Planned(1) Initial Surface Density (g/sq ft)	Relative Values $\bar{I}_m$ (mass/unit area)	Relative Values $\bar{R}_m$ (mass/unit area)	$\bar{F}$ (%)
FH	Dry	250	187	19	10
FH-HS-FH	Dry	250	886	41	4.6
FH	Dry	25	237	25	11.0
FH-HS-FH	Dry	25	221	15	6.8
FH-HSD-FH	Dry	25	95	12	13.0
FH	Slurry	125	910	26	2.9
FH-HS-FH	Slurry	125	807	23	2.9
FH-HSD-FH	Slurry	125	926	16	1.7
FH	Slurry	12.5	101	11	11
FH-HS-FH	Slurry	12.5	197	15	7.6
FH-HSD-FH	Slurry	12.5	324	11	3.4

(1) Slurry initial surface densities are on a dry weight basis.

TABLE 3.6 DECONTAMINATION RESULTS FOR ROLL ROOFING PANELS

Decontamination Procedure	Type of Contaminant	Planned[1] Initial Surface Density (g/sq ft)	Relative Values $\bar{I}_m$ (mass/unit area)	$\bar{R}_m$ (mass/unit area)	$\bar{F}$ (%)
FH	Dry	250	210	14	6.7
FH-HS-FH	Dry	250	1070	2.9	0.27
FH	Dry	25	320	4.3	1.3
FH-HS-FH	Dry	25	224	1.1	0.49
FH	Slurry	125	820	8.5	1.0
FH-HS-FH	Slurry	125	783	3.3	0.42
FH-HSD-FH	Slurry	125	898	1.6	0.18
FH	Slurry	12.5	86.5	6.2	7.2
FH-HS-FH	Slurry	12.5	161	5.0	3.1
FH-HSD-FH	Slurry	12.5	318	2.9	0.91

(1) Slurry initial surface densities are on a dry weight basis.

TABLE 3.7 DECONTAMINATION RESULTS FOR GALVANIZED CORRUGATED STEEL ROOFING PANELS

Decontamination Procedure	Type of Contaminant	Planned[1] Initial Surface Density (g/sq ft)	Relative Values $\bar{I}_m$ (mass/unit area)	$\bar{R}_m$ (mass/unit area)	$\bar{F}$ (%)
FH	Dry	250	245	7.5	3.1
FH-HS-FH	Dry	250	740	3.7	0.50
FH	Dry	25	266	7.6	2.8
FH-HS-FH	Dry	25	257	0.15	.053
FH	Slurry	125	820	4.2	0.51
FH-HS-FH	Slurry	125	606	3.3	0.54
FH-HSD-FH	Slurry	125	852	2.0	0.23
FH	Slurry	12.5	73.5	2.2	3.0
FH-HS-FH	Slurry	12.5	209	1.3	0.62
FH-HSD-FH	Slurry	12.5	265	2.0	0.75

(1) Slurry initial surface densities are on a dry weight basis.

TABLE 3.8 COST OF DECONTAMINATION PROCEDURES - PAVED AREAS

Decontamination Procedure	Type of Contaminant	Planned Initial Surface Density (g/ft^2)	Approx. cost of Equipment/Team (dollars)	Approx. Cost of Supplies/1000 ft^2 Gasoline (Gals)	Gasoline ($)	Detergent (Lbs)	Detergent ($)	Portland Cement Concrete Water (Gals/1000 ft^2)	PCC Men/team	PCC Rate (ft^2/min)	PCC Man hrs/1000 ft^2	Asphalt Water (Gals/1000 ft^2)	Asphalt Men/team	Asphalt Rate (ft^2/min)	Asphalt Man hrs/1000 ft^2
FH	Dry	250	1450	0.12	0.02	-	-	520	8	391	0.34	670	7	300	0.39
FH-HS-FH	Dry	250	1450	0.24	0.05	-	-	708	11	135	1.4	765	13	220	0.99
FH-HSD-FH	Dry	250	1450	0.25	0.05	2	0.60	526	11	166	1.1	-	-	-	-
MF	Dry	250	10,000	0.42	0.08	-	-	390	2	210	0.16	610	2	290	0.12
MF-MS-MF	Dry	250	20,000	1.78	0.36	0	0	-	-	-	-	715	3	94	0.53
MF-MSD-MF	Dry	250	20,000	1.30	0.26	2	0.60	-	-	-	-	563	4	129	0.52
FH	Dry	25	1450	0.10	0.02	-	-	885	11	225	0.81	340	9	590	0.25
FH-HS-FH	Dry	25	1450	0.19	0.04	-	-	735	15	187	1.3	565	13	270	0.80
FH-HSD-FH	Dry	25	1450	0.32	0.06	2	0.60	-	-	-	-	1130	13	132	1.6
MF	Dry	25	10,000	0.18	0.04	-	-	-	-	-	-	350	2	468	0.071
FH	Slurry	250	1450	0.18	0.04	-	-	1230	9	163	0.92	670	7	300	0.39
FH-HS-FH	Slurry	250	1450	0.18	0.04	-	-	-	-	-	-	675	13	232	0.94
FH-HSD-FH	Slurry	250	1450	0.22	0.04	2	0.60	805	11	192	0.95	-	-	-	-
MF	Slurry	250	10,000	0.64	0.13	-	-	935	2	123	0.27	737	2	142	0.23
MF-MS-MF	Slurry	250	20,000	1.12	0.22	-	-	-	-	-	-	587	3	149	0.34
MF-MSD-MF	Slurry	250	20,000	1.10	0.22	2	0.60	680	4	152	0.44	-	-	-	-
FH	Slurry	25	1450	0.23	0.05	-	-	1535	8	130	1.00	840	7	238	0.49
FH-HS-FH	Slurry	25	1450	0.20	0.04	-	-	1100	14	158	1.5	523	13	258	0.84
FH-HSD-FH	Slurry	25	1450	0.25	0.04	2	0.60	1100	10	142	1.2	645	13	266	0.82
MF	Slurry	25	10,000	0.16	0.03	-	-	363	2	486	0.069	328	2	544	0.061
MF-MS-MF	Slurry	25	20,000	1.64	0.33	-	-	945	3	101	0.50	-	-	-	-
MF-MSD-MF	Slurry	25	20,000	0.98	0.20	2	0.60	-	-	-	-	592	4	170	0.39

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CHAPTER 4

DISCUSSION OF RESULTS

4.1 EFFECTIVENESS OF DECONTAMINATION PROCEDURES

Although $\overline{F}$ (fraction remaining), where $\overline{F} = \overline{R}_m/\overline{I}_m$, has been used for effectiveness comparisons in various procedure-contaminant-surface tests, $\overline{F}$ was found to decrease with increasing initial mass, $\overline{I}_m$, and was relatively independent of the minor fluctuations of $\overline{R}_m$. It is because of this relationship and the varied initial mass levels of the tests that a comparison of $\overline{F}$ values may be misleading. Since $\overline{R}_m$ was relatively independent of $\overline{I}_m$, the values of $\overline{R}_m$ are used as the basic measure of decontamination and of the hazard remaining.

4.1.1 Effectiveness on Paved Areas

Excepting the special tests (Motorized Sweeping and Decontamination Truck - see section 4.1.1.6), Tables 3.1 and 3.2 show the effectiveness of all procedures to range as follows:

Dry Contaminant	$\overline{R}_m$ (mass/unit area)	$\overline{F}$ (percent)
Portland cement concrete	9.00 to 36.0	0.22 to 1.1
Asphaltic concrete	12.2 to 70.6	0.39 to 2.6
Slurry Contaminant		
Portland cement concrete	13.7 to 68.0	0.86 to 4.5
Asphaltic concrete	5.84 to 66.9	0.81 to 6.7

The one variable affecting the decontamination effectiveness not considered in the test planning is that of test surface condition. Tables 4.1 and 4.2 list the procedures tested for each contaminant-surface material combination according to their measured effectiveness. Included in the tables is an evaluation of test surface condition. The portland cement concrete and asphaltic concrete areas were each categorized into four ratings: excellent, good, fair and poor. The surfaces were judged on

Table 4.1 Effectiveness Against Dry Contaminant On Paved Areas. Correlation of $\bar{R}_m$ with Test Surface Condition.

Area No.	Decontamination Procedure	$\bar{R}_m$ (mass/unit area)	$\bar{F}$ (percent)	Surface Condition
Portland Cement Concrete - High Mass Level				
D-3	FH-HS-FH	19.5	0.22	Good
D-9	FH	27.0	0.32	Good
C-4	MF	32.0	0.43	Fair
E-2	FH-HSD-FH	36.0	0.43	Poor
Portland Cement Concrete - Low Mass Level				
D-8	FH-HS-FH	9.00	0.69	Fair
A-1	MF-MS-MF	9.81	0.73	Excellent
C-3	FH	26.9	1.1	Fair
Asphaltic Concrete - High Mass Level				
F-12	MF-MSD-MF	36.0	0.39	Excellent
F-11	MF	37.9	0.69	Excellent
H-3	MF-MS-MF	59.6	0.70	Fair
G-3	FH-HS-FH	61.0	0.85	Good
H-1	FH	70.6	0.97	Fair
Asphaltic Concrete - Low Mass Level				
H-4	FH-HSD-FH	12.2	0.87	Fair
F-8	MF	12.6	1.0	Excellent
G-4	FH-HS-FH	21.9	1.2	Poor
G-1	FH	49.4	2.6	Good

Table 4.2 Effectiveness Against Slurry Contaminant On Paved Areas. Correlation of $\bar{R}_m$ with Test Surface Condition.

Area No.	Decontamination Procedure	$\bar{R}_m$ (mass/unit area)	$\bar{F}$ (percent)	Surface Condition
Portland Cement Concrete - High Mass Level				
D-5	FH-HSD-FH	26.3	0.86	Fair
C-2	FH	35.7	1.0	Good
D-4	MF	56.3	1.1	Good
E-1	MF-MSD-MF	68.0	1.5	Poor
Portland Cement Concrete - Low Mass Level				
A-2	FH-HS-FH	13.7	1.9	Excellent
C-5	MF-MS-MF	29.0	4.5	Good
D-2	FH-HSD-FH	35.4	1.8	Good
B-1	MF	43.6	3.5	Poor
D-7	FH	45.8	3.7	Poor
Asphaltic Concrete - High Mass Level				
H-2	FH-HS-FH	39.6	1.2	Fair
F-7	MF	52.5	1.2	Excellent
F-9	MF-MS-MF	52.9	1.3	Excellent
F-3	FH	66.9	1.6	Excellent
Asphaltic Concrete - Low Mass Level				
F-10	FH-HSD-FH	5.84	0.81	Excellent
G-2	MF-MSD-MF	18.3	2.0	Good
F-4	FH-HS-FH	37.3	4.0	Excellent
F-2	MF	51.5	6.7	Excellent
F-6	FH	51.7	2.8	Excellent

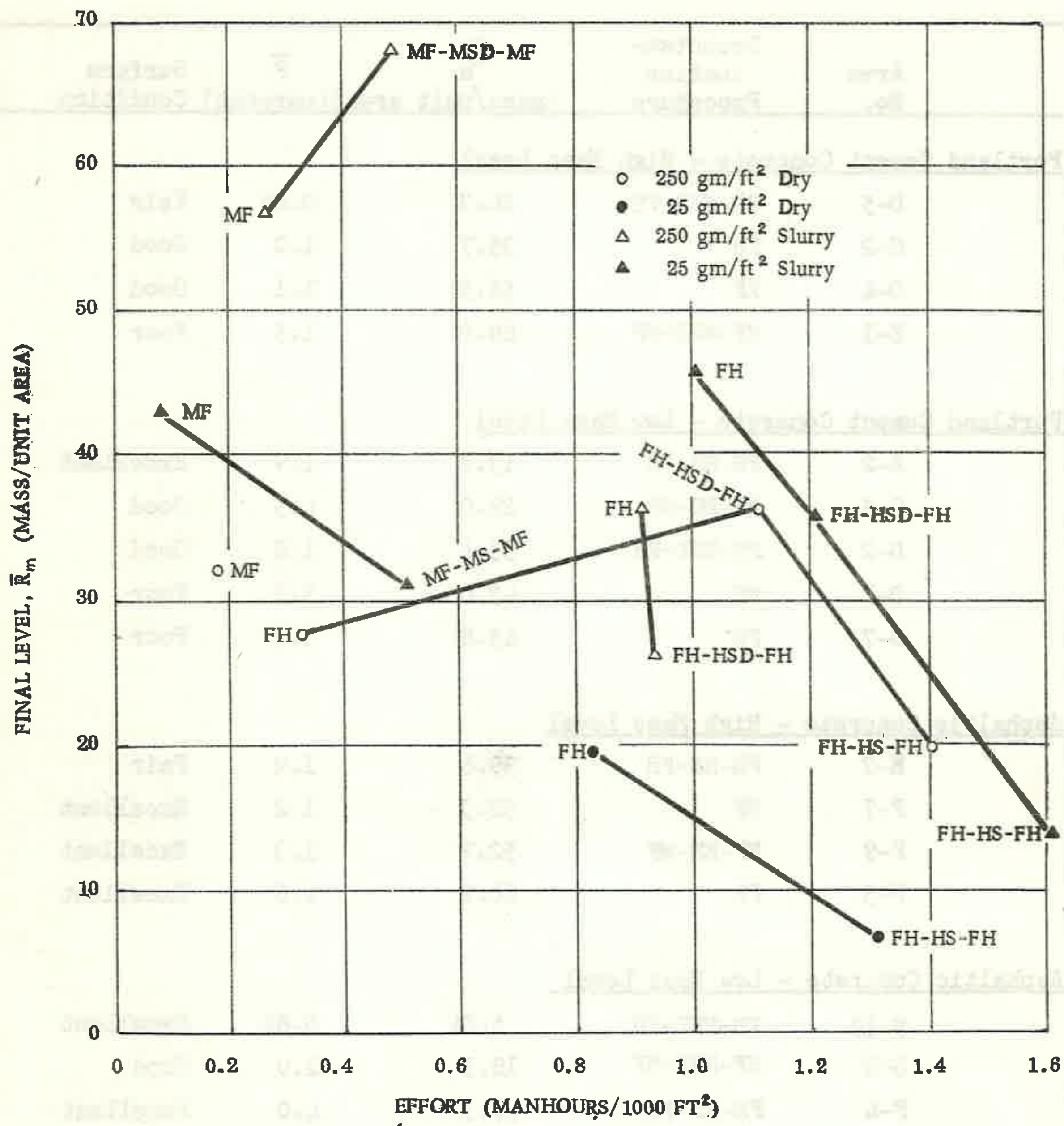


Fig. 4.1 Effort vs Final Level, for Portland Cement Concrete

frequency and severity of cracks, number of form lines, and lack of normal drainage. The ratings of the two surface types cannot be directly compared due to basic differences in the materials and surface roughness. For a visual indication of the surface condition of each test area, see the illustrations in Appendix B.

4.1.1.1 Portland cement concrete. From Tables 4.1 and 4.2, it can be seen that the procedures exhibiting the lowest residual mass per unit area in each group of similar tests were employed on surfaces rated fair, good, and excellent. The procedures resulting in the worst effectiveness values were tested on surfaces rated poor in three cases and fair in the fourth. Never did a "best" procedure and a "poor" surface coincide, nor did a procedure rank "worst" on an "excellent" surface.

It would appear, then, that the condition of the portland cement concrete test surfaces, as encountered at Camp Stoneman, has an influence on decontamination effectiveness.

4.1.1.2 Asphaltic concrete. From examining the values of $\bar{R}_m$ for the paved surfaces contaminated with the dry synthetic fallout, it is seen that the asphaltic concrete did not decontaminate as well as portland cement concrete, in spite of the generally better condition of the asphaltic concrete test surface. With slurry contaminant, the surface material seems to have no pronounced effect.

4.1.1.3 Type of contaminant. A comparison of the averages of the $\bar{R}_m$ values between the corresponding sections of Tables 4.1 and 4.2 reveals that slurry contaminant is consistently associated with the larger values. The same result is obtained in a parallel study employing the average of the $\bar{F}$ values (percent fraction remaining). Then, for like initial mass levels, slurry contaminant will, in all probability, be more difficult to remove than dry contaminant.

4.1.1.4 Effort versus final level. Figures 4.1 and 4.2 are plots of the average final values $\bar{R}_m$ from Tables 3.1 and 3.2 vs. the effort expended in manhours/1000 ft^2 from Tables 3.8 and 3.9, for each of the procedures evaluated on the paved areas. The data points on these figures are discrete, and the lines connecting points do not indicate a continuous function but are for convenience in comparing procedures conducted with the same type of synthetic fallout and the same approximate initial mass levels. From Figures 4.1 and 4.2 it can be seen that the motorized flushing procedure required less effort in all instances.

The effort expended in the motorized flushing procedure was dependent on the number of passes required to remove the material from the test area. In the tests conducted at the higher mass level (250 g/sq ft), it was found that one pass over the area was insufficient to remove all visible material, and several passes had to be made at a slower operating rate.

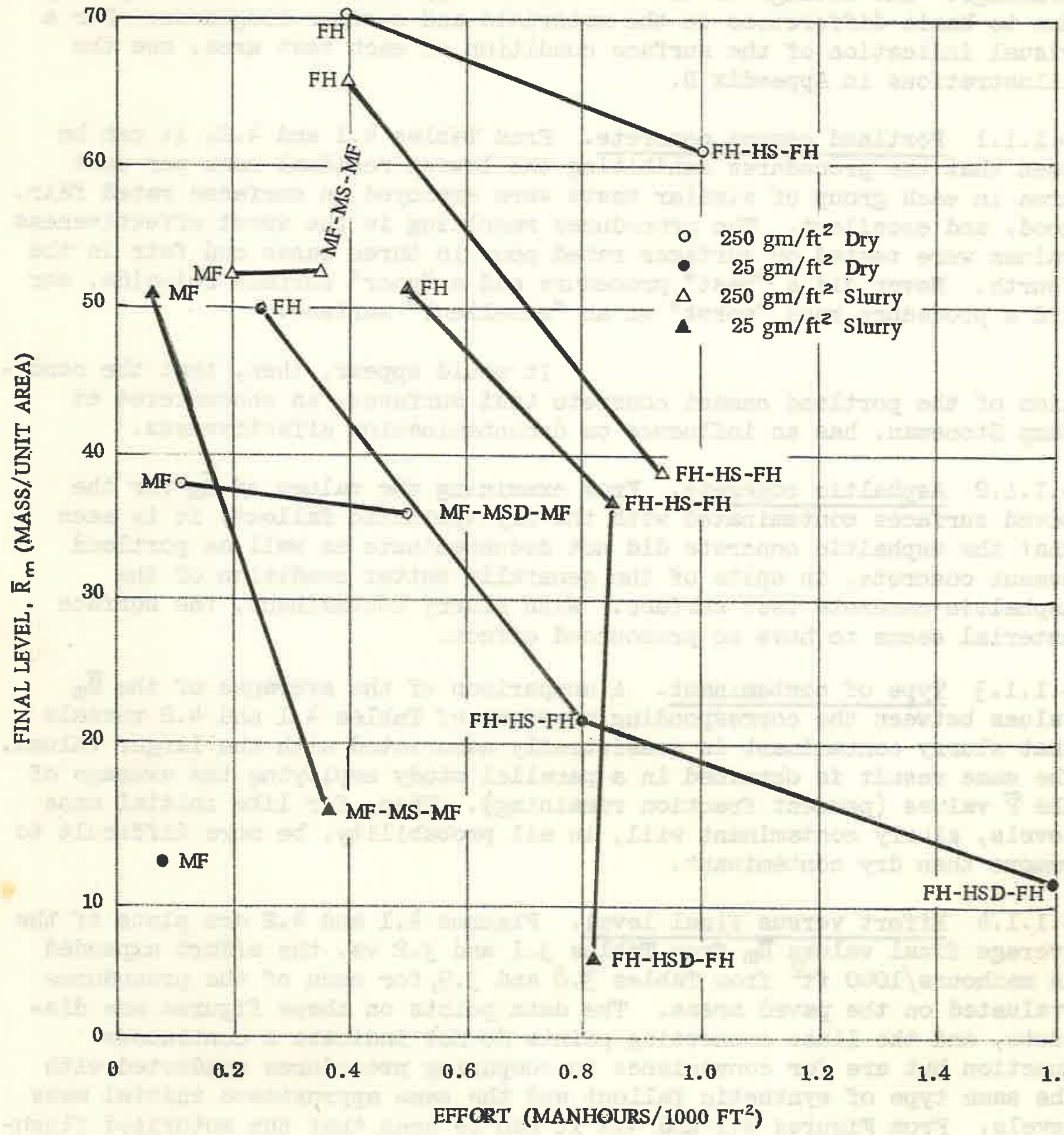


Fig. 4.2 Effort vs Final Level, for Asphaltic Concrete

In comparing the manual procedures, it is seen that more effort was expended in the procedures involving hand scrubbing with and without detergent than in the straight firehosing procedure. The resulting final levels were, in most instances, lower when the scrubbing procedures were used. One effect of the use of detergent with hand scrubbing, besides its ability to remove dirt and grease films from surfaces, was its action as a visible indicator. The foaming action provided a visual indicator showing areas scrubbed and those missed. This was especially true on the asphaltic concrete area contaminated with slurry synthetic fallout at the lower mass level. In this test, for the same amount of effort expended, the addition of detergent increased the effectiveness by a factor of 6.

As in the case of the addition of hand scrubbing to the firehosing procedure, the addition of motorized scrubbing to the motorized flushing procedure required an increase of effort. This increase, however, did not produce a significant increase in effectiveness at the higher mass levels. This may have been due to the manner in which the motorized sweeper was utilized. The broom on the sweeper did not contact the surface evenly and streaks of visible material were left on the surface after the sweeper passed over the area. An increase in effectiveness was noted at the lower mass levels.

4.1.1.5 Effect of area size and slope. To investigate the effect of area size and slope as a factor in the performance of the basic decontamination procedures, a special test was conducted on an 80 x 200-ft asphaltic concrete area (Area J) contaminated with dry material dispersed at the higher mass level (250 g/sq ft). The decontamination procedure used was motorized flushing. The results of this test are shown in Table 4.3. The area sloped downward from West to East and South to North. The flusher operated from West to East. As the material was removed from the test surface, it was transported along the resultant slope of the area towards the Northeast corner and the flushing was continued until the contaminant was removed to a sump 100 ft away. Successive passes by the flusher demonstrated that the flusher was limited in its capability to transport large quantities of material. A greater number of passes were required to move the material as the procedure progressed and material accumulated. To determine the effects of area size and slope, the final levels obtained were plotted vs. monitoring location along the long axis of the test area (Fig. 4.3). Four plots are shown, each plot represents the final values taken along a 20 ft strip of the test area (see diagram above graph). As indicated, the final levels were greater toward the North and East (the low) ends of the area where the build-up of contaminant became the heaviest. Final levels on Plots A and D differed by a factor of 4 (Table 4.3). Also on Figure 4.3 is a plot (dotted line) of the final levels obtained on the 20 x 200-ft asphaltic concrete test area (F-11) which was subjected to the same contaminant and recovery procedure as was

TABLE 4.3 RESULTS OF DECONTAMINATING AREA J. ASPHALTIC CONCRETE; MOTORIZED FLUSHING; DRY CONTAMINANT - APPROXIMATELY 250 G/SQ FT

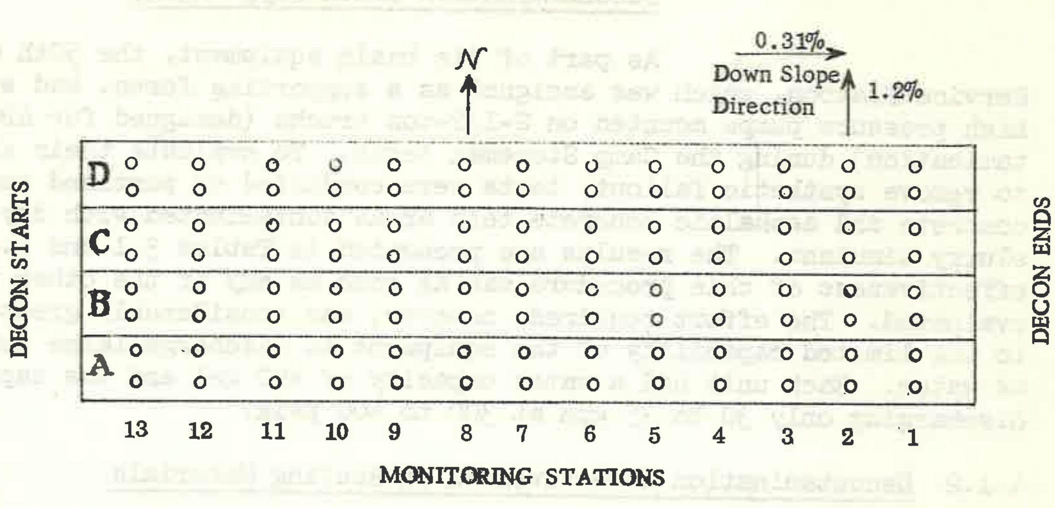
Section[a]	$\bar{I}_m$ (mass/unit area)	$\bar{R}_m$ (mass/unit area)	$\bar{F}$ (%)	Decon. Rate (ft^2/min)	Effort (manhours/1000 ft^2)
A	8,750	20.2	0.32	270	0.12
B	10,000	49.1	0.49	230	0.15
C	15,600	93.0	0.60	200	0.17
D	9,770	118	1.2	180	0.19

(a) See Fig. 4.3.

Area J. It is seen that the final levels were essentially constant over the entire area. This plot is similar to Plots A and B which represent the first two 20-ft sections of the large area. In examining the resulting operating rates and effort (Table 4.3) required to remove the mass of material on the large area, it is evident that a decrease in operating rate and therefore an increase in effort occurs as the procedure progresses from section to section. An operating rate of 290 ft^2/min was measured on the 20 x 200-ft test area (F-11) similarly contaminated and decontaminated, which compares closely with that achieved on Section A. Therefore, it may be stated that area size is an important factor in the removal of contaminant. The effectiveness of a procedure as stated previously is its ability to move the mass of material on the test surface to a waste disposal area. It would seem, therefore, that an increase in slope would reduce the removal effort for any procedure using water as a transporting medium.

4.1.1.6 Other tests: Motorized Sweeping.

Although the motorized flushing-motorized scrubbing procedure as applied to the test areas did not always show an appreciable increase in effectiveness over the motorized flushing procedure, the motorized sweeper could be utilized to remove a large percentage of the mass of dry material prior to the motorized flushing of large areas. To determine, on a preliminary basis, the effectiveness of the motorized sweeper used alone, tests were conducted on small (10 x 50 ft) asphaltic concrete and portland cement concrete areas using dry simulant at the high mass level. The results are indicated in Tables 3.1 and 3.2. Although the resultant average final mass levels are 20 to 30 times those obtained by the "wet" methods (FH, MF, etc.), the procedure removed 87 to 90 percent of the mass of the material present on test surfaces.



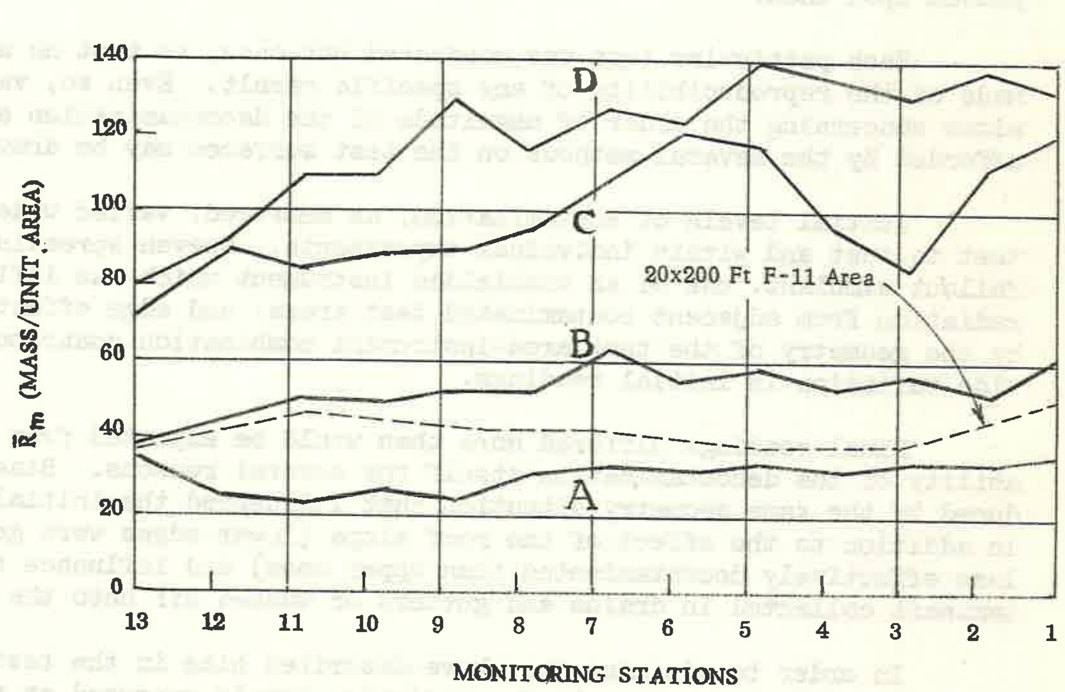


Fig. 4.3 Layout of Area J (top), and Final Levels ($\bar{R}_m$) vs Location of Readings

Decontamination Truck (Type M3A3)

As part of its basic equipment, the 50th Chemical Service Platoon, which was assigned as a supporting force, had several high pressure pumps mounted on 2-1/2-ton trucks (designed for ABC decontamination) during the Camp Stoneman tests. To evaluate their ability to remove synthetic fallout, tests were conducted on portland cement concrete and asphaltic concrete test areas contaminated with dry and slurry simulant. The results are presented in Tables 3.1 and 3.2. The effectiveness of this procedure was as good as any of the other procedures evaluated. The effort required, however, was considerably greater, due to the limited capability of the equipment to discharge large quantities of water. Each unit had a water capacity of 400 gal and was capable of discharging only 30 to 35 gpm at 300 to 400 psig.

4.1.2 Decontamination Effectiveness on Roofing Materials

It is necessary that the roofing decontamination data, presented in the tables of Chapter 3, be qualified so that proper significance is placed upon them.

Each particular test was conducted but once, so that no measure was made of the reproducibility of any specific result. Even so, valid conclusions concerning the order of magnitude of the decontamination effectiveness afforded by the several methods on the test surfaces may be drawn.

Initial levels of contamination, as measured, varied widely both from test to test and within individual experiments. Uneven spreading of the fallout simulant, use of an unshielded instrument which was influenced by radiation from adjacent contaminated test areas, and edge effects caused by the geometry of the test area-instrument combination contributed to this wide variation in initial readings.

Final readings differed more than would be expected from the variability of the decontamination itself for several reasons. Bias was introduced by the same geometry situation that influenced the initial readings, in addition to the effect of the roof slope (lower edges were generally less effectively decontaminated than upper ones) and influence from contaminant collected in drains and gutters or washed off onto the ground.

In order to minimize the above-described bias in the test results, it was decided to report only the radiation levels measured at the most central stations on each of the test areas. See Appendix D for location of stations used.

It was assumed that small differences in results of one procedure over another were not significant.

The initial and final values presented in Tables 3.3 to 3.7 are adjusted for specific activity variation as were the paved area data. Final level $\overline{R}_m$ are used as a measure of decontamination effectiveness instead of percent remaining, because the initial levels varied more than the final ones.

Generally, the final levels of contamination appear higher when the higher initial mass levels were applied.

Tables 3.3 through 3.7 indicate that the materials tested fell into two groups according to the decontamination effectiveness attained. The overall average R_m and F values were 3 times as great for the shingled roofs (wood and composition) as the average R_m and F values from the tar and gravel, roll roofing, and galvanized steel materials, regardless of procedure or contaminant.

Of the procedures, the data again being studied on an overall average basis, FH-HSD-FH is more effective by a factor of 1.5 on the $\overline{R}_m$ basis and 1.3 to 2.1 on the $\overline{F}$ basis, disregarding material and contaminant differences. Reasons for the apparent success of the FH-HSD-FH procedure: (1) the detergent aided in wetting the contaminant, particularly the smaller amounts of slurry; and (2) the foaming action provided a visual indicator showing areas scrubbed and those missed. Thus, a more complete coverage with scrubbing is made possible with minimum duplication of effort. This same result occurred on paved surfaces.

It was noted that the detergent used had a dissolving action on the bituminous materials in the composition shingles and roll roofing. The repeated application of detergents over protracted recovery periods may drastically shorten the life of such materials.

4.2 COST OF DECONTAMINATION

There are three major costs in radiological decontamination: time, money, and dosage to personnel. In this test, dosage to personnel is not considered, but since dosage is a function of time and the number of personnel involved, certain clues to the dosage cost are available in the data and are treated in Chapter 5.

In Tables 3.8 and 3.9, the time costs are presented in two fashions, rate, in ft^2/min/team, and effort, in manhours/1000 ft^2. These quantities are derived from measurements taken in the field and reflect the actual total of productive and non-productive time required to perform the decontamination indicated. These rates are not necessarily optimum, as no study of the effect of varied rates was made.

The monetary costs presented are estimates. The cost of equipment varies (Appendix E shows an equipment cost breakdown) and no accurate measure was made of the quantities of gasoline and detergent used. The cost of gasoline used per 1000 ft^2 is based on an estimate of 5 gallons per equipment hour at a price of $ 0.20 per gallon and an average of the productive rates of each procedure-contaminant combination on all of the surfaces tested. The amount of detergent consumed per 1000 ft^2 is also estimated.

The monetary value of the water consumed and the wages which were being paid to the men performing the operations have been omitted, as these costs would vary with the price per gallon and the wage per hour which are by no means constant over a range of situations. The number of gallons of water used and the number of men required per team are reported, however, so that these costs may be computed for a specific instance.

4.3 OPERATIONAL RESULTS

4.3.1 Simulant Preparation

The contaminant was prepared as described in section 2.1.3. Difficulty was experienced in the control of the simulant specific activity. This resulted from variation of the activity in the capsules as received because of scheduling problems at the Materials Testing Reactor at Arco, Idaho. Table F.1 in Appendix F indicates the uniformity of specific activity within batches of simulant and also the variation between them. See Reference 8 for details.

4.3.2 Simulant Dispersal

4.3.2.1 Paved areas. The amount of slurry dispersed, as determined by the sample pans, was found to be high for the scheduled 25 g/ft^2 amount and low for the 250 g/ft^2 amount. Although the average amounts of slurry material dispersed varied from the required amounts by a larger factor than the respective average amounts of dry material dispersed, the variation in the samples from each test area, as determined by standard deviation, was much less for the slurry material than for the dry material (see Appendix F).

4.3.2.2 Roof areas. The amounts actually dispersed over the roof areas and roofing panels were fairly close to the scheduled amounts of 250 and 25 g/ft^2 but large variations were experienced within each test area. It was difficult to maintain the proper rate of travel with the dispersers over the sloping roof areas (Appendix F).

4.3.3 Instrumentation

4.3.3.1 Shielded gamma instrument. The specific activity variations and, in a few cases, uneven contaminant distribution caused the shielded gamma instrument used on the paved areas to go off scale. This difficulty was resolved by adjusting the position of the detector relative to the lower face of the shield; the area viewed was reduced and the readings brought back on scale.

The data were corrected by an experimentally determined factor equal to the change in "seen" area when the detector position within the shield was changed.

The instrumentation and data-taking procedure will be described more fully, and the raw data taken during this field test will be presented.[14]

4.3.3.2 Unshielded gamma detection. Before the test series was completed, the G-M tube in the unshielded detector failed. The replacement tube exhibited slightly different response characteristics which were corrected in processing the data.

4.3.4 Radiological Safety

4.3.4.1 Dosimetry program. The maximum permissible whole-body exposure from external radiation was established at 3.9 r for the total operation. The maximum dosage received by all personnel engaged in test operations was less than 1.0 r.

4.3.4.2 Aerosol sampling. The control of the synthetic fallout material was such that airborne radioactive materials leaving the environs of the general test site were less than 1×10^{-9} microcuries (beta-gamma) per cubic centimeter of air, and no detectable amount of contaminant was deposited outside the test site.

CHAPTER 5

APPLICATION OF TEST RESULTS

5.1 INTERPOLATION OF TEST DATA

The revised version of the manual Radiological Recovery of Fixed Military Installations, NAVDOCKS TP-PL-13, U. S. Army TM 3-225 (now in process of being published), outlines detailed planning for radiological recovery in the event of nuclear disaster. Planning values of 300, 1000, and 3000 r/hr initial standard dose rates are presented as being typical in expected situations.

The initial standard dose rates planned for use in this series of tests were 1000 and 10,000 r/hr. Before the results reported in Chapter 3 can be applied in operational planning as described in the manual, it would be desirable that they be modified to fit the planning dose rates of 300, 1000, and 3000 r/hr. However, the authors do not feel that the test data justify extrapolation, beyond the limits of the experimental data, to the 300 r/hr dose rate at H + 1 hour. It was tacitly assumed that the condition of the surfaces, method of application, weather, etc., in this test were typical of expected situations.

Between the limits of 1000 and 10,000 r/hr a linear interpolation between the average residual and average initial standard dose rates for each set of test conditions is conveniently chosen to compare performance information for each procedure-contaminant-surface combination. Rather than adjustment of the 95% confidence intervals rigorously on the basis of an assumed linear relationship, the less restrictive approach of assuming linearity between the limits of the confidence intervals is used. This type of analysis simply considers that the variability of the final levels achieved is typical of that expected in actual situations. However, in those cases where extrapolation was necessary in analyzing the variability of standard dose rates between 1000 and 10,000 r/hr, and where the resultant or extrapolated interval was narrower than the smaller of the two observed intervals, the latter was used.

Figure 5.1 is a typical example of the technique used to determine the 95 percent confidence interval of the final standard dose rate corresponding to initial standard dose rates of 1,000 and 3,000 r/hr.

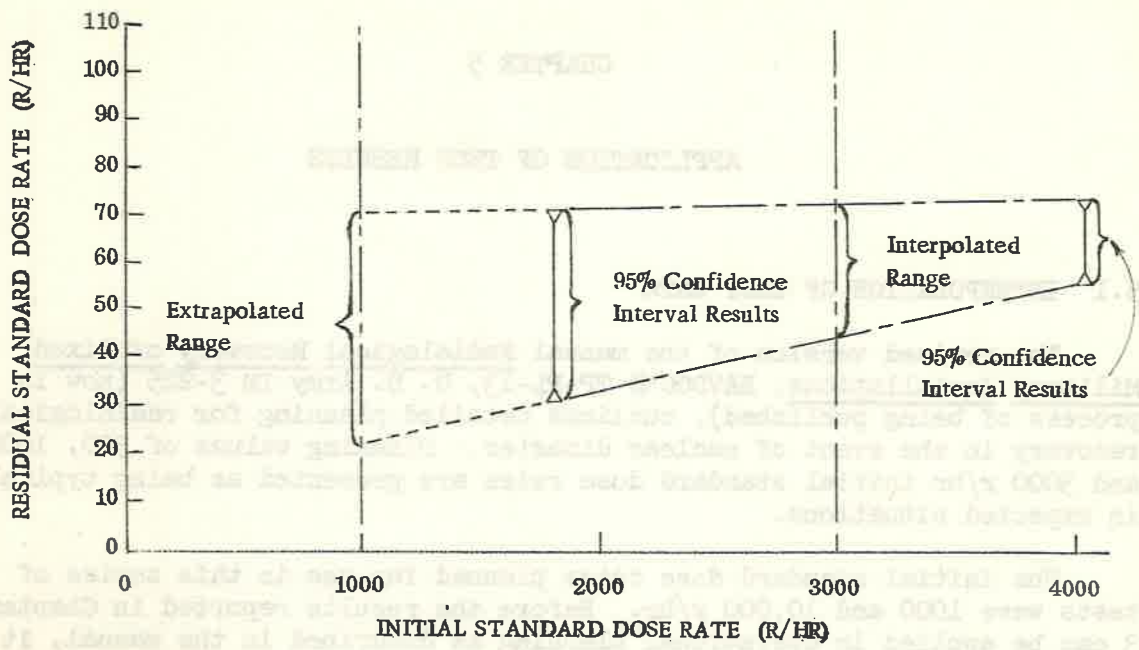


Fig. 5.1 Example of Interpolation and Extrapolation to Obtain Residual Values Corresponding to Initial Dose Rates of 1000 and 3000 r/hr (fire-hosing, asphaltic concrete, slurry).

Tables 5.1 through 5.6 are the results of the interpolation technique and give the expected recovery performance of the decontamination procedures most likely to be used under actual conditions on paved areas and roofs exposed to dry and slurry fallout. The expected recovery performance figures for roofing materials, Tables 5.3 through 5.6, were devised from very limited data and although no range of values were included in the tables, because data was lacking, they must be considered as "extremely wide." Consequently, where only small differences are shown, these differences are not considered significant or real.

The effectiveness of the procedures is indicated by presenting both the residual standard dose rate* and the residual number.** Normally the residual standard dose rate, when decayed to the time of interest, is of greater significance to the planner.

*Residual standard dose rate: dose rate existing after decontamination and referred to one hour after burst.

**Residual number: $\frac{F}{100}$. This term is used in the manual Radiological Recovery of Fixed Installations.[1]

Table 5.1 Expected Recovery Performance on Asphaltic Concrete Exposed to Dry Contaminant

PROCEDURE	1000 r/hr Initial Standard Dose Rate					3000 r/hr Initial Std Dose Rate				
	Resid'l Std. Dose Rate r/hr	Effectiveness[b] Residual Number	Plann'g Rate 1000 ft² / hr	No. of men	Effort[c] Man hrs / 1000 ft²	Resid'l Std. Dose Rate r/hr	Effectiveness[b] Residual Number	Plann'g Rate 1000 ft² / hr	No. of Men	Effort[c] Man hrs / 1000 ft²
Column	1	2	3	4	5	1	2	3	4	5
Motorized Flushing	8-16	.01	35	2	0.06	18-32	.006-.01	35	2	0.06
Firehosing	<1-100[d]	.04	15	6-8	0.4-0.5	16-94[d]	.02	15	6-8	0.4-0.5
FH-HSD-FH[a]	12-19	.01-.02	10	11-13	1.1-1.3	26-38	.01	10	11-13	1.1-1.3

Table 5.1 Expected Recovery Performance on Portland Cement Concrete Exposed to Dry Contaminant

PROCEDURE	1000 r/hr Initial Standard Dose Rate					3000 r/hr Initial Std Dose Rate				
	Resid'l Std. Dose Rate r/hr	Effectiveness[b] Residual Number	Plann'g Rate 1000 ft² / hr	No. of Men	Effort[c] Man hrs / 1000 ft²	Resid'l Std. Dose Rate r/hr	Effectiveness[b] Residual Number	Plann'g Rate 1000 ft² / hr	No. of Men	Effort[c] Man hrs / 1000 ft²
Column	1	2	3	4	5	1	2	3	4	5
Motorized Flushing	6-12[e]	.01	35	2	0.06	8-27	.003-.009	35	2	0.06
Firehosing	19-34	.02-.03	15	6-8	0.4-0.5	18-35	.006-.01	15	6-8	0.4-0.5
FH-HSD-FH[a]	6-11	.01	10	11-13	1.1-1.3	9-14	.003-.005	10	11-13	1.1-1.3

[a] Firehosing plus handscrubbing with detergent followed by a second firehosing.

[b] Residual number, as a measure of effectiveness, is the ratio of residual standard dose rate/initial standard dose rate: column 1/I.

[c] Effort, in man hr/1000 ft², results from dividing the number of men involved by the planning rate: $\frac{\text{column 4}}{\text{column 3}}$.

[d] Poor specific activity data provided an extremely large confidence interval.

[e] This data from MF-MS-MF test results, and it is assumed that the MS operation did not add to the decontamination effectiveness.

Table 5.3 Expected Recovery Performance on Asphaltic Concrete Exposed to Slurry Contaminant

PROCEDURE	1000 r/hr Initial Standard Dose Rate					3000 r/hr Initial Std Dose Rate				
	Resid'l Std. Dose Rate	Effectiveness[b]	Plann'g Rate	No. of Men	Effort[c]	Resid'l Std. Dose Rate	Effectiveness[b]	Plann'g Rate	No. of Men	Effort[c]
	r/hr	Residual Number	1000 ft²/hr		Man hrs/1000 ft²	r/hr	Residual Number	1000 ft²/hr		Man hrs/1000 ft²
Motorized Flushing	44-58	.05	28	2	0.07	47-57	.02	28	2	0.07
Firehosing	24-70	.03-.07	9	6-8	0.7-0.9	50-74	.02	9	6-8	0.7-0.9
FH-HSD-FH[a]	34-41	.04	9	11-13	1.2-1.4	36-42	.01	9	11-13	1.2-1.4

Table 5.4 Expected Recovery Performance on Portland Cement Concrete Exposed to Slurry Contaminant

PROCEDURE	1000 r/hr Initial Standard Dose Rate					3000 r/hr Initial Std Dose Rate				
	Resid'l Std. Dose Rate	Effectiveness[b]	Plann'g Rate	No. of Men	Effort[c]	Resid'l Std. Dose Rate	Effectiveness[b]	Plann'g Rate	No. of Men	Effort[c]
	r/hr	Residual Number	1000 ft²/hr		Man hrs/1000 ft²	r/hr	Residual Number	1000 ft²/hr		Man hrs/1000 ft²
Motorized Flushing	35-52	.04	28	2	0.07	43-56	.01-.02	28	2	0.07
Firehosing	36-55	.04	9	6-8	0.7-0.9	36-55[e]	.01-.02	9	6-8	0.7-0.9
FH-HSD-FH[a]	8-62[d]	.01-.06	9	11-13	1.2-1.4	8-62[e]	.003-.02	9	11-13	1.2-1.4

[a] Firehosing plus handscrubbing with detergent followed by a second firehosing.

[b] Residual number, as a measure of effectiveness, is the ratio of residual standard dose rate/initial standard dose rate: column 1/I.

[c] Effort, in man hr/1000 ft², results from dividing the number of men involved by the planning rate: $\frac{\text{column 4}}{\text{column 3}}$.

[d] Inconsistent results provided the wide range. See Table 4.2.

[e] The range was expanded and adjusted to equal the width and magnitude of the 1000 r/hr values.

Table 5.5 **Expected Recovery Performance on Roofs Exposed to Dry Contaminant**

SURFACE and PROCEDURE	1000 r/hr Initial Standard Dose Rate					3000 r/hr Initial Std Dose Rate				
	Resid'l Std. Dose Rate	Effec- tiveness[b]	Plann'g Rate	No. of men	Effort[c]	Resid'l Std. Dose Rate	Effec- tiveness[b]	Plann'g Rate	No. of Men	Effort[c]
	r/hr	Residual Number	$\frac{1000\ ft^2}{hr}$		$\frac{Man\ hrs}{1000\ ft^2}$	r/hr	Residual Number	$\frac{1000\ ft^2}{hr}$		$\frac{Man\ hrs}{1000\ ft^2}$
Column	1	2	3	4	5	1	2	3	4	5
Corrugated Metal										
Firehosing	29	.03	3.9	2	0.5	30	.01	3.9	2	0.5
FH-HSD-FH[a]	5	.005	4.8	5	1.0	12	.004	3.9	5	1.3
Tar and Gravel										
Firehosing	38	.04	1.5	4	2.7	38	.015	1.5	4	2.7
FH-HSD-FH[a]	10	.01	1.8	7	3.9	31	.01	1.8	7	3.9
Roll Roofing										
Firehosing	54	.05	3.0	2	0.7	54	.02	3.0	2	0.7
FH-HS-FH	15	.015	3.9	5	1.3	30	.01	3.3	5	1.5
Composition Shingle										
Firehosing	60	.06	3.0	2	0.7	70	.02	3.0	2	0.7
FH-HS-FH	31	.03	3.0	5	1.7	46	.015	2.7	5	1.8
Wood Shingle										
Firehosing	100	.10	2.1	2	1.0	200	.07	2.1	2	1.0
FH-HS-FH	50	.05	1.5	5	3.3	100	.03	1.5	5	3.3

[a] Firehosing plus handscrubbing with detergent followed by a second firehosing.

[b] Residual number, as a measure of effectiveness, is the ratio of the residual standard dose rate/initial standard dose rate: column 1/I.

[c] Effort, in man hrs/1000 ft^2, results from dividing the number of men involved by the planning rate: column 4/column 3.

Table 5.6 Expected Recovery Performance on Roofs Exposed to Slurry Contaminant

Surface and Procedure	1000 r/hr Initial Standard Dose Rate					3000 r/hr Initial Std Dose Rate				
	Resid'l Std. Dose Rate	Effectiveness[b]	Plann'g Rate	No. of men	Effort[c]	Resid'l Std. Dose Rate	Effectiveness[b]	Plann'g Rate	No. of Men	Effort[c]
	r/hr	Residual Number	1000 ft²/hr		Man hrs/1000 ft²	r/hr	Residual Number	1000 ft²/hr		Man hrs/1000 ft²
Column	1	2	3	4	5	1	2	3	4	5
Corrugated Metal										
Firehosing	30	.030	2.7	2	0.7	38	.013	2.7	2	0.7
FH-HSD-FH[a]	7	.007	3.0	5	1.7	17	.006	2.7	5	1.8
Tar and Gravel										
Firehosing	55	.055	1.5	4	2.7	55	.018	1.5	4	2.7
FH-HS-FH	45	.045	1.8	7	3.9	50	.017	1.8	7	3.9
Roll Roofing										
Firehosing	120	.12	1.8	2	1.1	120	.04	1.8	2	1.1
FH-HS-FH	55	.055	3.0	5	1.7	55	.018	2.7	5	1.8
Composition Shingle										
Firehosing	250	.25	1.8	2	1.1	250	.083	1.8	2	1.1
FH-HS-FH	170	.17	2.4	5	2.1	200	.067	2.4	5	2.1
Wood Shingle										
Firehosing	250	.25	1.5	2	1.3	250	.083	1.5	2	1.3
FH-HS-FH	170	.17	0.9	5	5.6	200	.067	0.9	5	5.6

[a]Firehosing plus handscrubbing with detergent followed by a second firehosing.

[b]Residual number, as a measure of effectiveness, is the ratio of the residual standard dose rate/initial standard dose rate: column 1/I.

[c]Effort, in man hrs/1000 ft², results from dividing the number of men involved by the planning rate: column 4/column 3.

The planning rates and effort indicated consider the time involved in setting up equipment and moving from area to area and include a 75 percent efficiency adjustment in productive effort.

Information concerning the removal of fallout resulting from deep-water-surface and subsurface bursts are included to increase the scope. Seawater fallout, depending on humidity, might arrive as wet saturated salt particles or as water droplets, much like rain. When these droplets or salt particles strike a surface they tend to stick where they hit and the contaminant becomes tenacious by attaching to the surface. The residual numbers obtained when nondestructive decontamination procedures are used to remove wet fallout are high, and to obtain low residual numbers, it appears that destructive decontamination techniques will be required which remove some of the surface of the paving or roofing material.

Table 5.7 presents the recovery performance of the procedures applicable to areas contaminated by wet fallout. Here only a range of expected residual numbers are given since existing data is limited in applicability. The information is a composite of laboratory, and Operations SAN BRUNO[3] and CASTLE[16] results.

Table 5.8 presents the recovery performance on unpaved areas which primarily reflect the results of Operation JANGLE.[2] The performance of earth-moving in the removal and burial of radioactive fallout is assumed independent of type and amount of contaminant.

The planning values presented in Tables 5.1 through 5.8 are based on a specific weapon detonation-environment system which results in a mass-radiation relationship of 25 $mg/ft^2/r/hr$ at 1 hour. When the recommended procedures are used in an actual situation, repeated readings of dose rate should be made to determine if modifications of the recovery plan are necessary.

5.2 GENERAL DECONTAMINATION CONSIDERATIONS

The mode of operation with the procedures described here is to start at the higher points and progress down, so that the contaminant is carried with the run-off away from the cleaned areas.

In built-up areas, where run-off from the roofs of buildings would recontaminate the streets, the work on the roofs should advance ahead of that on the streets. Unpaved areas such as backyards, etc., would be decontaminated concurrently with the streets.

Table 5.7 Expected Recovery Performance on Paved Areas and on Roofs Exposed to Wet (ionic) Contaminant

Surface	Procedure	Range of Effectiveness[b] (Residual Number)	Planning Rate (1000 ft^2/hr)	No. of Men	Range of Effort[c] Man hrs/1000 ft^2
Pavements Concrete or Asphalt	Motorized Flush'g	.50 - .75	27	2	.07
	Firehosing	.55 - .85	9	6-8	0.7-0.9
	FH-HSD-FH[a]	.35 - .55	9	11-13	1.2-1.4
	Heater Planer[d]	.04 - .06	4 - 8	3 -4	.4 - 1.0
Roofs					
Tar and Gravel	Firehosing	.20 - .30	1.5	4	2.7
	FH-HSD-FH[a]	.05 - .15	1.8	7	3.9
Roll Roofing	Firehosing	.65 - .85	3.0	2	0.7
	FH-HS-FH	.20 - .50	2.4	5	2.1
Comp. Shingles	Firehosing	.65 - .85	3.0	2	0.7
	FH-HS-FH	.25 - .55	2.4	5	2.1
Corrg. Metal	Firehosing	.60 - .90	2.4	2	0.8
	FH-HS-FH	.40 - .55	1.8	5	2.8
Wood Shingles	Firehosing	.75 - .85	2.4	2	0.8
	FH-HS-FH	.35 - .75	1.8	5	2.8

[a] Firehosing plus handscrubbing with detergent followed by a second firehosing.

[b] Residual number, as a measure of effectiveness, is the ratio of the residual standard dose rate/initial standard dose rate.

[c] Effort, in man hours/1000 ft^2, results from dividing the number of men involved by the planning rate.

[d] Restricted to surface removal of asphalt paving only. Greater rate based on use of skip loader for truck with debris. Lesser rate relies on 2 laborers to shovel debris into truck. The results of this destructive decontamination method shows that surface removal techniques are required to achieve low residual numbers.

Table 5.8 Expected Recovery Performance of Earth Removal Procedures on Unpaved Sandy Soil Exposed to Unspecified Types of Nuclear Weapon Debris.

Procedure	Range of Effectiveness* (Residual Number)	Range of Planning Rates (1000 ft²/hr)	No. of Men	Range of Effort** (Man hr/1000 ft²)
Earth Removal				
Powered Scraping	.1 - .2	15-42[a]	4.0[a]	.09-.26
Motorized Grading[b]	.1 - .2	20-30	1.0	.03-.05
Bull Dozing[c]	.1 - .2	2-13	1.0	.08-.50
Earth Filling[g]				
Powered Scraping	.1 - .2	9-30[a]	4.0[a]	.13-.43
Dumping and Grading	.1 - .2	20-30[d]	8.0[d]	.27-.40
Burial[h]				
Gang Plowing	.1 - .2	< 35	1.0	> .029
Combinations				
Scraping and Filling	.01-.04	6-24[e]	5.0[e]	.21-.83
Scraping and Plowing	.01-.04	< 30[f]	5.0[f]	> .17

[a] Based on three scrapers.

[b] Is effective on smooth terrain only.

[c] Is effective for short passes only.

[d] Requires approximately six dump trucks and one power shovel for each grader.

[e] Based on three scrapers.

[f] Based on three scrapers and one bulldozer per gang plow.

[g] Based on minimum of 6" fill.

[h] Based on 6" to 8" depth of burial.

* Residual number, as a measure of effectiveness, is the ratio of the residual standard dose rate/initial standard dose rate.

** Effort, in man hrs/1000 ft^2, results from dividing the number of men involved by the planning rate.

In areas where buildings are set well back from the streets, the order in which the work should be done is streets first, buildings next, and unpaved areas last. In any case the necessity for decontaminating an area should be given careful consideration.

5.3 SPECIFIC DECONTAMINATION PROCEDURES

The planning rates given in Tables 5.1 through 5.8, as indicated in section 5.1, take into account the time involved in setting up equipment, moving from area to area and a 75 percent production efficiency factor. Rates are presented in this section which are operating rates recommended for use by the decontamination teams.

5.3.1 Paved Areas

5.3.1.1 Firehosing (FH). The FH procedure, because of the common availability of its equipment and the flexibility of its application, could be used for a quick and gross decontamination. The equipment, personnel, and operating procedure would be generally as outlined in section 2.4.1. Booster pumps may or may not be required depending upon available fire hydrant pressure. A nozzle pressure of about 80 psig is recommended. The recommended operating rates (sq ft/min/hose) on paved areas are:

Contaminant		
Dry	Slurry	Wet
150	100	100

5.3.1.2 Motorized Flushing (MF). The MF procedure is recommended for use on streets and large paved areas when street flushers are available. The equipment, personnel, and operating procedure would be generally as outlined in section 2.4.1. The street flushers could be used in conjunction with firehoses that would be used on sidewalks and sides of buildings. To supplement the available flushing equipment, improvised street flushers can be easily assembled with the use of flat bed trucks, water tanks, pump, and the necessary piping. See Fig. 5.2. The recommended operating rates (sq ft/min/flusher) on paved areas are:

Contaminant		
Dry	Slurry	Wet
650	550	500

5.3.1.3 Firehosing, Hand Scrubbing, Firehosing (FH-HS-FH). The FH-HS-FH procedure is recommended when the expected residual radiation level, as indicated in Tables 5.1 to 5.4 for firehosing and motorized flushing, is too high. Detergent should be used with the scrubbing when available.

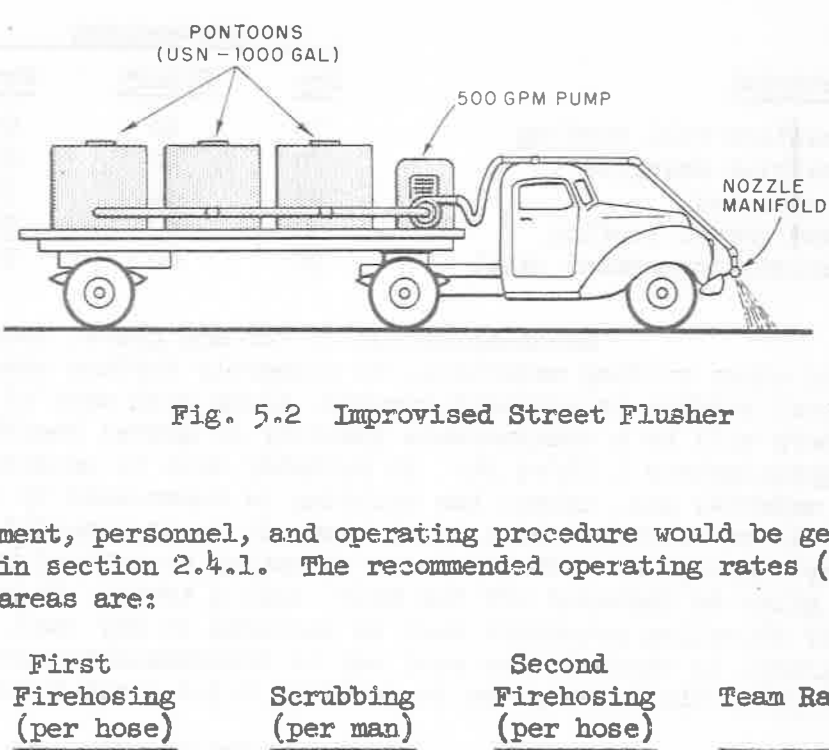


Fig. 5.2 Improvised Street Flusher

The equipment, personnel, and operating procedure would be generally as outlined in section 2.4.1. The recommended operating rates (sq ft/min/team) on paved areas are:

First Firehosing (per hose)	Scrubbing (per man)	Second Firehosing (per hose)	Team Rate
250	40	165	200

5.3.2 Roofs

One consideration in pre-attack planning for the recovery of roofs is to insure adequate access to the roofs. During operation, equipment and hoses can be moved from one building to the next by the use of lines strung between buildings. Ladders will be required in many instances.

After decontamination of the roof of a building, a thorough hosing of the walls, window sills, ledges, etc., should be accomplished to remove initial contaminant and contaminant transported from the roof. Gutters and drains should be flushed out thoroughly after the roof surface has been cleaned.

5.3.2.1 Firehosing (FH). The firehosing procedure is recommended as the primary decontamination procedure on building roofs because of equipment availability and operational simplicity. The equipment, personnel, and operating procedure would be generally as outlined in section 2.4.2. The use of booster pumps is recommended to maintain a minimum nozzle pressure of 60 psig. The recommended operating rates (sq ft/min/hose) on the various roofing materials are:

Material	Contaminant Dry	Slurry	Wet
Composition roll roofing	70	40	65
Composition shingles	70	40	65
Wood shingles	45	30	55
Tar and gravel roofing	60	45	50
Galvanized corrugated steel	90	60	55

Decontamination of tar and gravel roofing, unlike that of other roofing materials, is primarily surface removal. The loose gravel surface is actually removed, along with most of the contaminant. There will be a considerable quantity of gravel removed from each roof, approximately 1 lb/sq ft. It probably will be necessary to contain this material and, unless the building is surrounded by unpaved areas which will be recovered at a later time, it is recommended that the gravel be swept into piles with firehoses operating at reduced pressure and that the piles be shoveled off the roof, into a truck. On roofs with parapets, this shoveling procedure must be included in any case. When most of the gravel is removed, the roof may be decontaminated with the chosen procedure at the rates given in sections 5.3.2.1 and 5.3.2.2.

5.3.2.2 Firehosing, Hand Scrubbing, Firehosing (FH-HS-FH). The FH-HS-FH procedure is recommended when the anticipated residual radiation levels, as indicated in Tables 5.5 and 5.6, by firehosing alone are too high. Detergents should be used with the scrubbing whenever possible. The equipment, personnel, and operating procedure would be generally as outlined in section 2.4.2. The recommended operating rates (sq ft/min/team) on the various materials are:

Material	First Firehosing (per hose)	Scrubbing (per man)	Second Firehosing (per hose)
Composition roll roofing	250	45	150
Composition shingles	250	45	100
Wood shingles	100	25	50
Tar and gravel roofing	50	40	100
Galvanized corrugated steel	300	30	200

5.4 RADIATION EXPOSURE CONSIDERATIONS

5.4.1 Recovery Patterns

During recovery of land-based installations, decontamination teams will accumulate radiation dosages proportional to the radiation intensity and to the exposure time. Because it imposes a limit upon the efforts contributed by all decontamination personnel, dosage must be considered when estimating the cost of recovery operations.

The magnitude of the dose accumulated by recovery personnel is a function of conflicting factors. Effective removal of the radiation source or contaminant tends to reduce the over-all dose, while at the same time the requirement for teams to work constantly in the radiation field contributes steadily to an increase in dose. This latter condition persists even though 100 percent removal of the contaminant is achieved during a given recovery operation. Thus, in addition to using the most effective decontamination technique at hand, recovery teams must also adhere to certain rules governing their movements in and about a contaminated area in order to realize additional savings in dose.

In general, decontamination teams will be confronted by two basic situations:

A. Working from a clean zone into a contaminated area.

B. Working from within a large contaminated zone (as when first emerging from a shelter).

Situation A is the least serious, since recovery personnel are being irradiated from only the recovery front* and in the event that dosages are accumulating at an excessive rate, teams can retire to the clean zone. This may not be the case for Situation B, where teams are being irradiated from all sides and when the retirement area or shelter may not afford adequate protection.

It is, therefore, apparent that the following recovery patterns or rules should be observed during recovery operations as a means of further limiting the over-all dose.

Rule A. Maintain as wide and as reasonably straight a recovery front as is commensurate with the available manpower, equipment and area configuration. This means the avoidance of pocketing (see Fig. 5.3) and the widening of fronts to at least 35 to 40 ft.

Such a pattern is particularly applicable to Situation A when teams assault an isolated area such as a contaminated roof or street.

*The recovery front is the moving border dividing clean and contaminated areas.

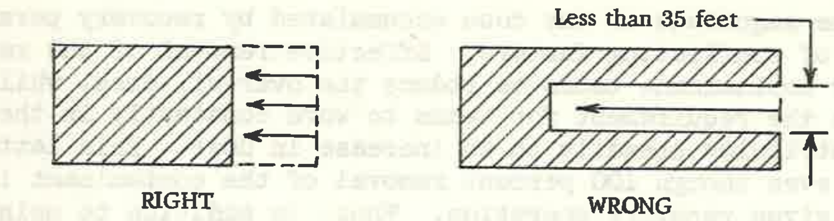


Fig. 5.3 Schematic Representation of Rule A.

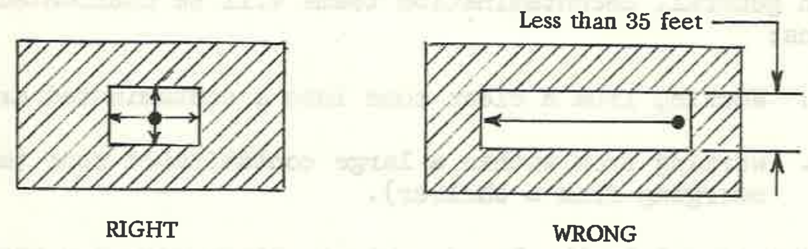


Fig. 5.4 Schematic Representation of Rule B.

Rule B. Work radially from the starting point. That is, expand the area equally toward the four compass points whenever possible (Fig. 5.4) until at least one dimension of 35 to 40 feet is obtained.

For Situation B a decontamination team within an extensive, contaminated zone would use Rule B to great advantage, since the creation of clean areas in the shape of narrow corridors or pockets would not form a pattern for maximum protection.

5.4.2 Estimation of Dosage

The total dose rate felt at the recovery front is made up largely from the initial radiation intensity, X, existing at the center of the contaminated area prior to decontamination. Fortunately only a fraction of X impinges upon the front. This amount equals $\emptyset X$ where $\emptyset$ varies between 0 and 1 depending upon the size (and shape) of the area in question.[15]

The curves in Fig. 5.5 demonstrate this relationship. Values for ϕ shown along the horizontal axis represent average fractional intensities which can be felt at the midpoint of a front during the exposure period required to clean square-shaped areas extending over the size ranges shown along the vertical axis.

It will be noted that all curves asymptotically approach a demarcation line located at a fractional intensity of 0.5. Curves to the left of this value fit Situation A, those to the right fit Situation B.

The remaining portion of the total intensity at the recovery front is contributed by the residual intensity, Y, from the decontaminated area. Again, only a fraction of the intensity reaches the front. This fraction must equal 1 - ϕ since the total of fractional intensities, X_t, from both cleaned and contaminated areas cannot exceed unity. Therefore, the total intensity along the front is

$$X_t = \phi X + Y(1 - \phi) \qquad (5.1)$$

By definition Y = FX, where F is the residual number for a given decontamination procedure. Substituting into Eq 5.1 and multiplying by the stay time, T, gives the dose,* D, accumulated at the front

$$D = X_t T = XT\left[\phi + F(1 - \phi)\right] \qquad (5.2)$$

For a particular recovery procedure (which fixes F) employed on a known area of a given intensity, X, the curves of Fig. 5.5 may be used to find ϕ, and Eq 5.2 can then be solved for the dose to recovery personnel.

5.4.3 Recovery Dose Index

Among the time costs of recovery listed in section 5.3 is effort. It is defined in the units of manhours per 1000 ft^2 and can be represented by a simple equation

$$E = \frac{MT}{A}, \qquad (5.3)$$

where M = number of men per decontamination team
T = stay time
A = number of unit areas (1000 ft^2) cleaned.

Solving for T and substituting in Eq. 5.2,

$$D = X\left[\phi + F(1 - \phi)\right]\frac{EA}{M} \qquad (5.4)$$

*Corrections for decay have been ignored here.

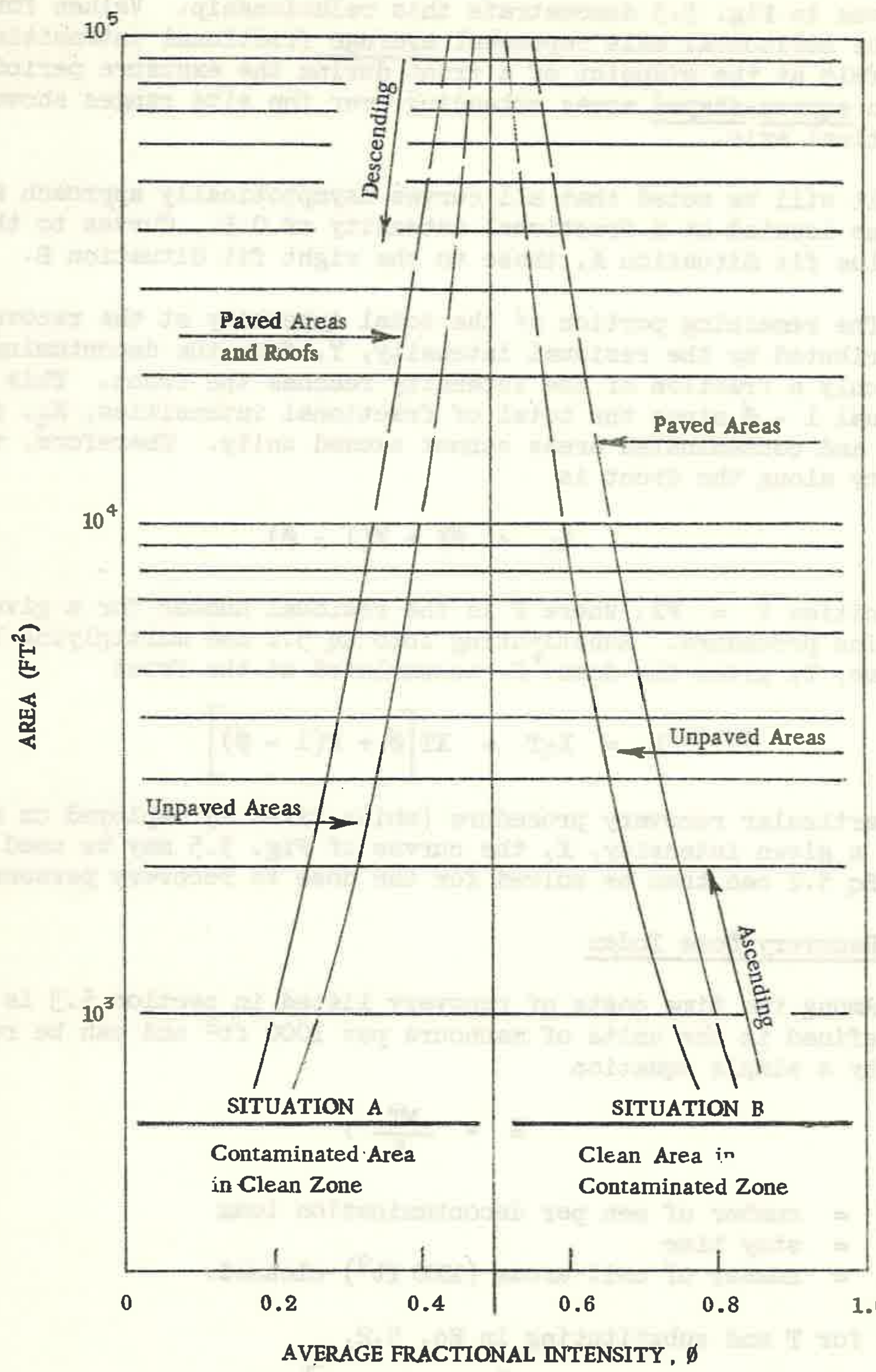


Fig. 5.5 Fraction of Frontal Intensity as a Function of Area Size

Thus, it is possible to predict recovery dose without actually stipulating the stay time. Practical considerations, however, would impose a daily upper limit of about eight hours. In view of this limit and an assumed entry time of H + 24 hours or later, both Eqs 5.2 and 5.4 have neglected to account for savings in dose due to the effects of decay.

By rearranging terms in Eq 5.4 a still more useful expression results,

$$\frac{MD}{XA} = E\left[\phi + F(1 - \phi)\right] . \qquad (5.5)$$

An examination of the right-hand term discloses that all three variables may be estimated prior to nuclear attack. ϕ is determined by area size and configuration, while F and E are known for a number of decontamination procedures (Tables 5.1 to 5.8). Thus, the expression can be solved in advance for a variety of expected situations peculiar to a given target. This solution of the right-hand term of Eq 5.5 is called the Recovery Dose Index or RDI. Whence

$$\overline{RDI} = E\left[\phi + F(1 - \phi)\right] \qquad (5.6)$$

and

$$\overline{RDI} = \frac{MD}{XA} . \qquad (5.7)$$

Inspection of Eq 5.7 reveals the significance of the RDI. It is the man-dose per unit intensity (at entry time) for each unit area of 1000 ft^2 that is cleaned. Once an RDI is computed it remains only to multiply it by the number of unit areas and the intensity and divide it by the number of men to obtain recovery dose. Or, expressed mathematically from Eq 5.7,

$$D = \overline{RDI}\,\frac{XA}{M} . \qquad (5.8)$$

By treating the problem in two steps, the chore of planning recovery operations on the basis of dosage considerations is greatly lessened. An assortment of RDI's can be computed at any time prior to attack using Eq 5.6. Then, when a contaminating situation arises, Eq 5.8 becomes an extremely simple means of determining dosage to recovery personnel. This equation is also useful in finding suitable values for X, A, and M when some predetermined magnitude of D is not to be exceeded. It is even possible to solve Eq 5.8 for a wide range of predicted intensities, X, and further speed the recovery planning phase.

Equations 5.2 and 5.8 give the dosage to unshielded persons; i.e., those engaged in manual procedures such as firehosing or hand scrubbing. The values derived from these expressions should be halved[2] when applied to heavy equipment operators since the dose will be reduced due to shielding effects. The term equipment used here refers to such rolling stock as trucks, tractors, motorized graders, motorized scrapers, street flushers, street sweepers, etc., which will normally be available for recovery of land and paved areas.

It should be noted that the values for ϕ were derived from suitable data tabled in Reference 15 (Tables I G and II G). This information (and hence the values of ϕ) resulted from a mathematical development founded on several idealized conditions. The basic condition included an infinite plane uniformly contaminated by a 0.7-Mev monoenergetic source. All radiation intensities or dose rates were assumed to be measured at a height of three feet above this plane. Appropriate corrections for scattering were made in accordance with the findings of Goldstein and Wilkins.[17]

5.4.4 Example of Dosage Calculation

One of the more difficult recovery situations would be that confronting a decontamination team emerging from a shelter amidst contaminated surroundings. To simplify the example that follows, it will be assumed that the shelter is located in the middle of a large paved area. One decontamination team equipped to institute a FH-HS-FH procedure is housed within the shelter. It is also assumed that the detailed recovery pattern will coincide with Rule B (section 5.4.1).

Objective: Determine the recovery dose to personnel engaged in removal of dry contaminant for a standard dose rate* of 1000 r/hr.

Given: Standard dose rate at one hour, 1000 r/hr
For entry time of 46 hours, intensity (or dose rate) X is 10 r/hr
Recoverable area contains approximately 20,000 ft^2
Type of contaminant, dry
Decontamination procedure, FH-HS-FH
Recovery pattern, Rule B.

Preliminary Findings: From Table 5.1, under the multiple column heading captioned "1000 r/hr Initial Standard Dose Rate" find
Residual Number, F = 0.015
Effort, E = 1.1-1.3; average, 1.2
No. of Men, M = 11-13; average 12.

Also Given: Number of unit (1000 ft^2) areas, A = 20,000/1000 = 20.

*A direct equivalence between intensity and dose rate is assumed.

From Fig. 5.5 for an area of 20,000 ft^2, the average value of ϕ = 0.63.

Solution: Substitute the proper values into Eq 5.6 and solve for RDI:

$$\overline{RDI} = E\left[\phi + F(1 - \phi)\right]$$

$$\overline{RDI} = 1.2\left[0.63 + 0.015(1 - 0.63)\right]$$

$$\overline{RDI} = 0.76.$$

From Eq 5.8 the dose per man is

$$D = \overline{RDI}\,\frac{XA}{M}$$

$$D = 0.76\left(20\,\frac{10}{12}\right)$$

$$D = 12.7\ r\ .$$

Because Eq 5.8 does not take into account the additional decrease in dose due to natural decay, the value found for D is a conservative estimate of the dose (D > the decay-corrected value). For any particular instance it is possible to compute how much D exceeds the theoretically true value based on a $t^{-1.2}$ decay scheme.

If there had been no recovery operation and personnel remained in the contaminated area from 46 to 48 hours their dose D_T would have been

$$D_T = Y_o \int_{t_1}^{t_2} t^{-1.2}\,dt \ , \qquad (5.9)$$

where Y_o = standard dose rate at one hour. Substituting the proper values and solving,

$$D_T = 1000 \int_{46}^{48} t^{-1.2}\, dt$$

$$D_T = 5(1000)\left[\frac{1}{46^{0.2}} - \frac{1}{48^{0.2}}\right]$$

$$D_T = 5000(0.4657 - 0.4611)$$

$$D_T = 18 \text{ r} .$$

Had decay been ignored, the approximate dose D_A then would have been equal to the product of entry dose rate and stay time.

$$D_A = Y_e(t_2 - t_1) \qquad (5.10)$$

where Y_o = dose rate at entry. Substituting the proper values and solving,

$$D_A = 10(48 - 46)$$

$$D_A = 20 \text{ r} .$$

The differences between the approximate, D_A, and theoretically correct, D_T, values for dose is 2 r, and the percent error resulting from using Eq 5.10 rather than Eq 5.9 is 11 percent. Since Eq 5.8 neglects decay contributions in much the same way as Eq 5.10 does, the previously calculated values for D = 12.7 r is also 11 percent high. Thus, the decay-corrected value is more nearly equal to 11.4 r.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

6.1.1 Effectiveness of Decontamination

With few exceptions, the decontamination procedures removed 95 percent of the dry and slurry contaminants. The residual amount of contaminant is relatively independent of the initial amount of contaminant.

6.1.1.1 Paved areas.

a. The condition of the surface being decontaminated has an influence on decontamination effectiveness.

b. Dry contaminant is more completely removed from portland cement concrete than asphaltic concrete.

c. The decontaminability of the two paving materials is similar for slurry contamination.

d. For similar initial amounts of contaminant, the slurry contaminant will be more difficult to remove than the dry contaminant.

6.1.1.2 Roofing areas.

a. Of the tested procedures the FH-HSD-FH procedure is the most effective.

b. The removal of contaminant is easier by a factor of 3 from galvanized steel, roll roofing, and tar and gravel roofing than from composition shingles and wood shingles, regardless of procedure or type of contaminant.

c. The residual amounts of the dry and slurry contaminants are similar.

6.1.2 Cost of Decontamination

6.1.2.1 Paved areas.

a. The tested procedures ranked by increasing cost (effort) are MF, lowest; MF-MS-MF, MF-MSD-MF, and FH, greater than MF by a factor of 3; and FH-HS-FH and FH-HSD-FH, greater than MF by a factor of 6.

b. Using the FH procedure on a poor portland cement concrete surface requires twice the effort of that for a good asphaltic concrete surface.

6.1.2.2 Roofing areas.

a. The tested procedures ranked by increasing effort are FH, lowest; and FH-HS-FH and FH-HSD-FH, greater than FH by a factor of 3.

b. The tested roofing materials ranked according to the effort required to decontaminate them are composition shingles, roll roofing and galvanized steel, lowest; tar and gravel roofing, greater by a factor of 1.3; and wood shingles, greater by a factor of 2.

6.1.3 Synthetic Fallout

The use of synthetic fallout in field operations of the nature and scope of the Camp Stoneman Operation is satisfactory.

6.2 RECOMMENDATIONS

The following lines of further investigation are suggested for inclusion in future development of countermeasures for land targets and the ultimate use of information so far obtained.

a. Determination of the relationship between recovery effectiveness and those factors affecting operational efficiency in order to define optimum performance characteristics of the basic decontamination procedures.

b. Development and testing of new reclamation techniques for land targets with emphasis on waterless decontamination procedures such as motorized sweeping, vacuum cleaning, etc.

c. Study of the effects of lesser amounts of contaminant on the surfaces tested.

d. Continuance of the development of synthetic fallout materials for use in studies of earth moving decontamination methods.

e. Investigation of the availability of existing equipment that could be utilized or modified in performing the basic decontamination methods as outlined.

f. Evaluation of the basic decontamination procedures on areas contaminated with a suitable "wet" synthetic fallout.

g. Evaluation of the influence of slope and surface roughness of target components on the performance of the basic decontamination procedures.

Approved by:

E. R. Tompkins

E. R. TOMPKINS
Head, Chemical Technology Division

For the Scientific Director

Fig. A.1 Layout of Test Areas.

Area A:	Portland Cement Concrete
Area B:	Portland Cement Concrete
Area C:	Portland Cement Concrete
Area D:	Portland Cement Concrete
Area E:	Portland Cement Concrete
Area F:	Asphaltic Concrete
Area G:	Asphaltic Concrete Street
Area H:	Asphaltic Concrete Street
Area J:	Asphaltic Concrete
CS Roofs:	Composition Shingle
TG Roofs:	Tar and Gravel
Test Panels:	Wood Shingle, Corrugated Galvanized Steel, Roll Roofing.

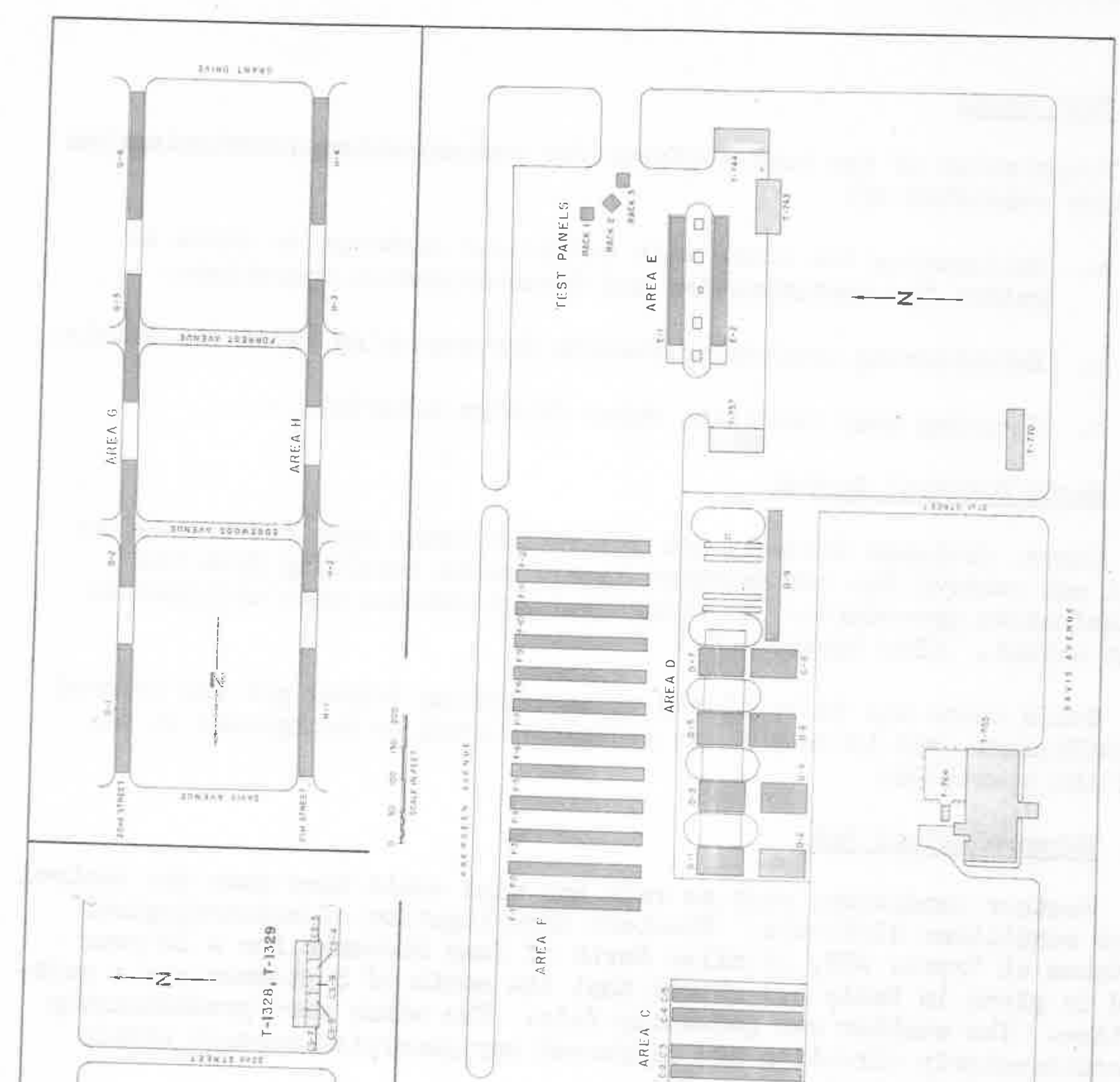

AREA A
AREA B
AREA C
AREA D
AREA E
AREA F
AREA G
AREA H
AREA J
TEST PANELS
T-1302
T-1311
T-1315
T-1328, T-1329
T-601
DAVIS AVENUE
EDGEWOOD AVENUE
FORREST AVENUE
GRANT DRIVE
ABERDEEN AVENUE
N

Figure A.1.

A.2.1 Test Areas

Preparation of the test surfaces for contamination-decontamination activities consisted of:

a. Delineating the areas with sufficient markings to serve as guides for contamination and decontamination operations.

b. Establishing monitoring station for measuring radiation levels.

c. Clearing away weeds and other foreign material.

A.2.2 Waste Disposal System

Dikes, drainage ditches, and collection sumps were constructed to collect and control the contaminated liquid waste resulting from the decontamination procedures. Existing drainage ditches were utilized to a great extent. (See Appendix B.)

Solid waste was to be placed in an existing borrow pit and covered with sufficient soil to reduce the radiation level to background at the end of the operation.

A.2.3 Meteorological Data

Weather conditions such as rain and wind would have made the control of test conditions difficult. Pre-test investigation of meteorological data taken at Travis AFB, 17 miles North of Camp Stoneman,for a 10-year period is given in Table A.1 showed that the month of September was a suitable time. The weather was generally fair. The winds were predominantly in a southwesterly direction and dispersed any generated aerosol within the confines of the test area.

A.2.4 Radiological Safety Preparations

To insure that safe radiological conditions were maintained for personnel engaged in the Operation at Camp Stoneman and in the surrounding areas, a radiological safety group was formed. Pre-test rad-safe preparations were:

a. Procuring monitoring instruments, dosimetry equipment and protective clothing supplies.

b. Converting a two-story barracks into a personnel decontamination center which served the following functions: personnel clothing change and decontamination center, radioanalysis counting room, dosimetry equipment issue center, and protective clothing storage and issue.

TABLE A.1 Meteorological Data from Travis Air Force Base (Fairfield-Suisun Station, California) 17 mi North of Camp Stoneman for 10 Year Period 1945 to 1955

AUGUST			SEPTEMBER		
Wind Velocity			Wind Velocity		
Av. of Daily Maxima	Direction	Monthly Per Cent	Av. of Daily Maxima	Direction	Monthly Per Cent
17 k	W	2.0	11 k	W	2.6
17 k	WSW	29.2	13 k	WSW	26.3
13 k	SW	56.6	16 k	SW	47.1
17 k	SSW	7.4	16 k	SSW	8.0
			15 k	NNE	3.0
Light and Variable - Balance 4.8			Light and Variable - Balance 13		
Rainfall (av.)		0.01"	Rainfall (av.)		0.06"
Temp. (Av. of Daily Maxima)		109.0°F	Temp. (Av. of Daily Maxima)		108.0°F
Temp. (av.)		70.4°F	Temp. (av.)		70.9°F
Min. Temp. (av.)		47.0°F	Min. Temp. (av.)		39.0°F

c. Installing a permanent wind speed and wind direction instrument to obtain wind data for the test period.

d. Training military personnel assigned to the radiological safety group in the performance of their duties.

e. Positioning of aerosol sampling equipment for continuous air sampling at the periphery of the test site.

f. Placing radiological signs and rope barriers around test areas and buildings to be contaminated.

APPENDIX B

SURFACE CONDITIONS, SLOPE CHARACTERISTICS, AND SPECIAL DRAINAGE FACTORS

This appendix describes the areas on which the tests were conducted: the surface conditions, the slopes, and the control of drainage from the areas.

B.1 SURFACE CONDITIONS - PAVED AREAS

B.1.1 Concrete

Areas A, B, C, D, and E (Fig. A.1) were laid out on portland cement concrete surfaces of two textures: smooth (Area A) and rough "broomed finish" (Areas B, C, D, and E).

In Area A, the form lines or expansion joints, filled with an asphalt compound, were spaced at approximately 40-ft intervals perpendicular to the long axis. In Areas B and E, there were form lines spaced from 5 to 15 ft apart perpendicular to the long axis, and a center form line running parallel to the long axis. None of these form lines were filled with tar. In Areas C and D, the form lines divided the surface into 11 x 11-ft and 15 x 15-ft squares. This form line pattern was broken in Area C by what appeared to be a reconstructed section, oblong in shape, and having a slightly smoother surface texture than the surrounding area. Portions of this section were within Areas C-2 and C-3. None of the form lines in Areas C and D contained a filler material. All the form lines mentioned were not less than 1/4 in. in width.

As shown in Fig. B.1, Area A was relatively free from cracks; the cracks shown were not greater than 1/8 in. in width. Areas B-1 and B-2 had many cracks greater than 1/4 in. in width and tar had been used to repair some of the cracks in Area B-2. Severe cracking was present in Area C-1 while the remainder of the C areas were moderately cracked. Some spalling had occurred around the edges of the oblong area (Areas C-2 and C-3, Fig. B.1). With the exception of hairline cracks in the C areas, all cracks were greater than 1/4 in. in width. Area D (Fig. B.2) was relatively free from cracks with the exception of Area D-7 which was severely cracked; however, these cracks were less than 1/4 in. in width. Area E-1, however,

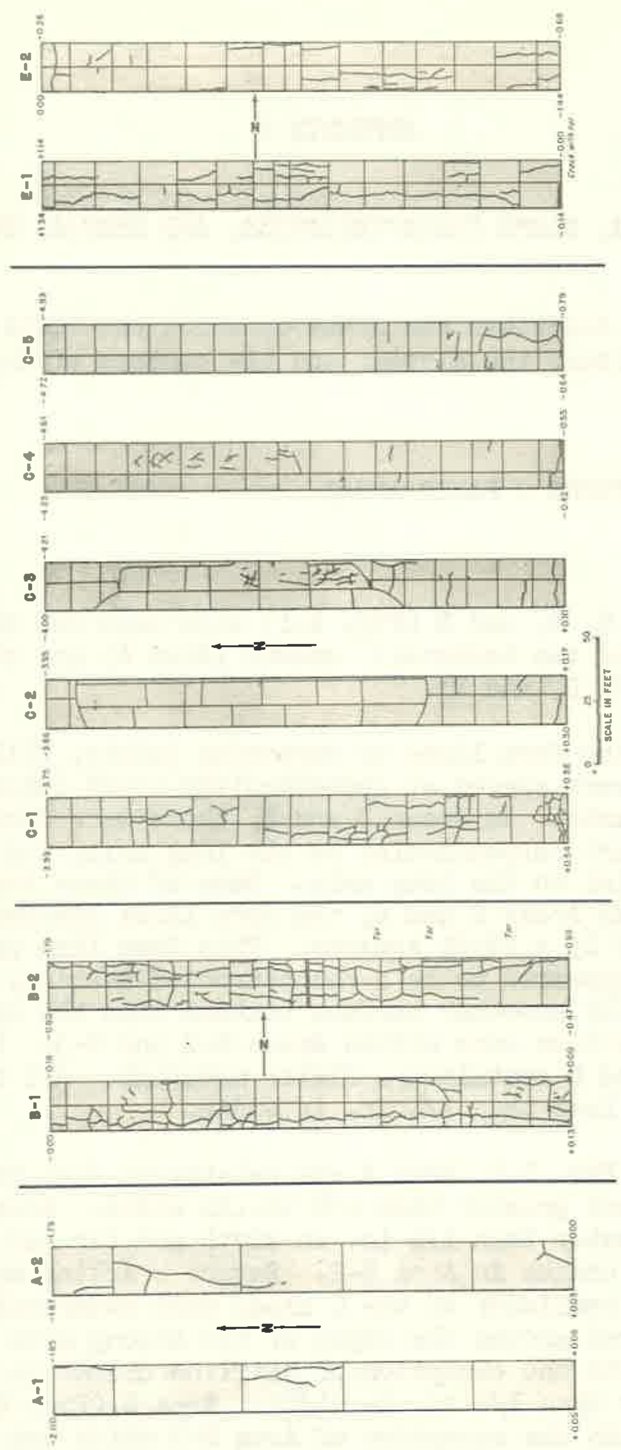


Fig. B.1 Slopes, Form Lines, and Cracks in Areas A, B, C, and E, Portland Cement Concrete

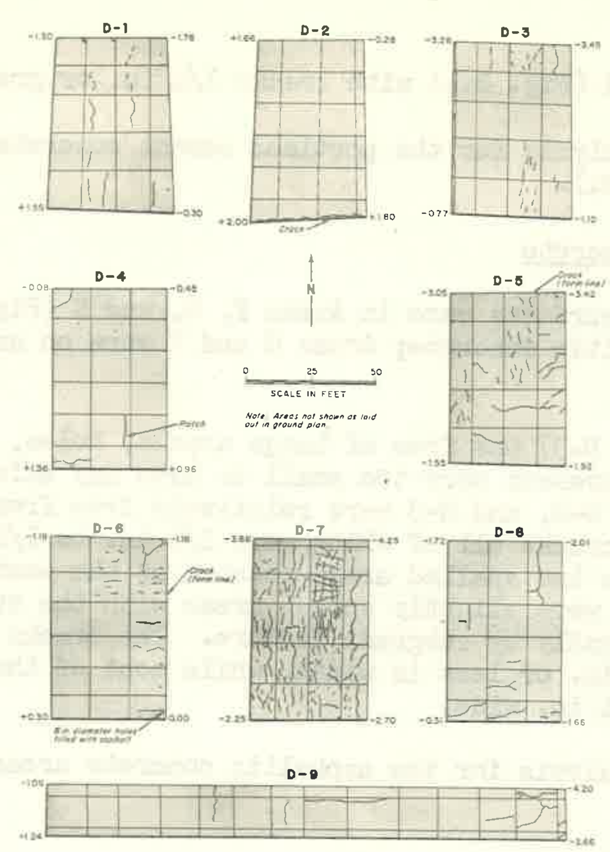


Fig. B.2 Slopes, Form Lines, and Cracks in Area D, Portland Cement Concrete.

was severely cracked (Fig. B.1) with cracks 1/4 in. or greater.

The slope analysis for the portland cement concrete areas is presented on Table B.1.

B.1.2 Asphaltic Concrete

The asphalt surfaces were in Areas F, G, and H (Fig. A.1). Area F was of smooth asphaltic concrete; Areas G and H were on asphalt-macadam, crowned roadways.

Area F (Fig. B.3) was free of large cracks, holes, or patches. The several cracks present were too small to have any effect on decontamination. Areas G-1, G-2, and G-3 were relatively free from cracks. Area G-4 contained numerous cracks all of which were 1/8 in. to 1/4 in. in width. Note in Fig. B.4 the two spalled areas located at the west edges of Areas G-1 and G-4. These were slightly sunken areas with the surface considerably cracked, caused probably by subgrade failure. The cracks in Areas H-1 and H-2 were fine, 1/8 in. or less in width, while most of the cracks in Areas H-3 and H-4 were 1/4 in. wide.

The slope analysis for the asphaltic concrete areas is in Table B.2.

B.2 DRAINAGE CONDITIONS

In order to contain the contaminated water running off from decontamination and thereby prevent recontamination of other areas, small dikes were built and several sumps were dug.

An earth dike two feet high was constructed along the east edge of Area A. Another dike was built on the north edge of Area B and joined to the dike east of Area A, to protect Area B which was to be decontaminated later.

Dikes were constructed from the northwest and northeast corners of Area C to a large drainage ditch north of the paved area (Fig. A.1).

To contain the washoff from Area D, the northernmost semicircular areas adjacent to Areas D-1, D-3, D-5, and D-7 (Fig. A.1) were dug out to a depth of 2 to 3 ft. Dikes were constructed along the north ends of Areas D-1, D-3, D-5, and D-7 to channel the run-off into these sumps. Run-off threatening to accumulate in the rectangular areas adjacent to D-1, D-3, D-5 and D-7 was carried away by underground drains discharging in a large drainage ditch.

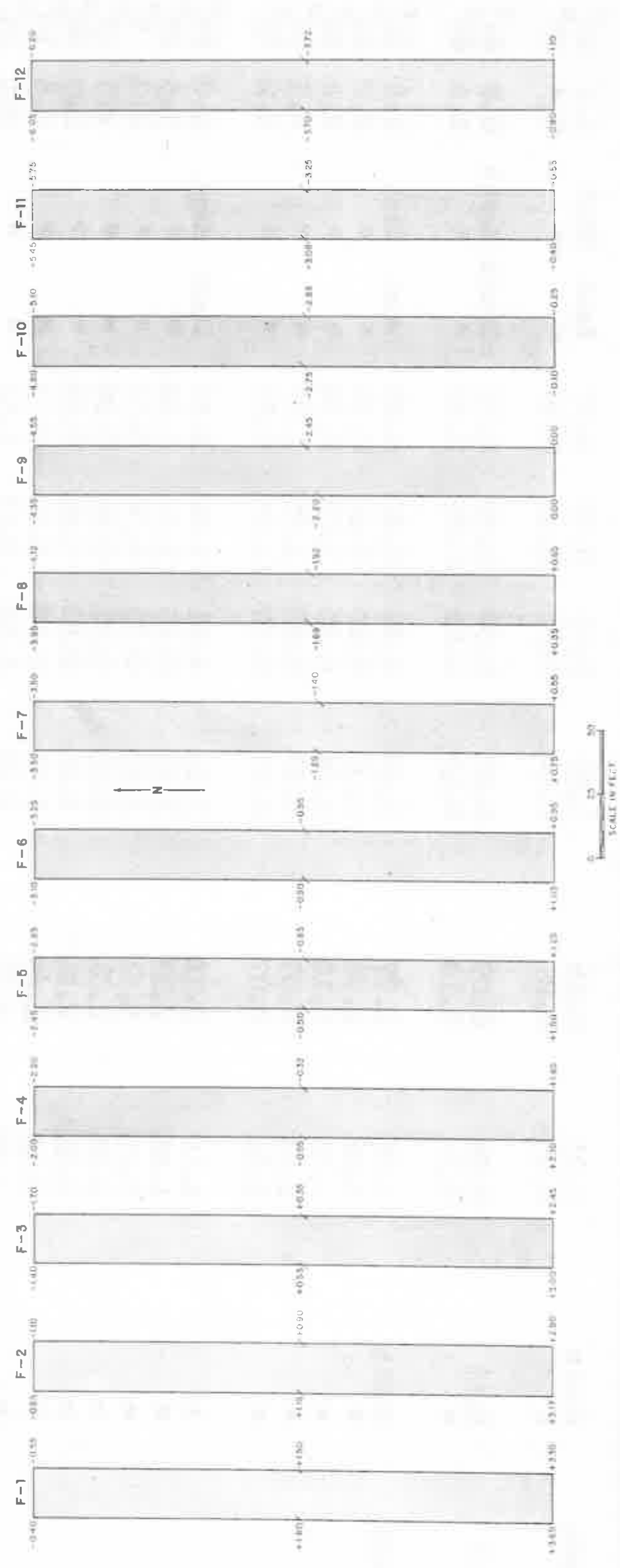


Fig. B.3 Slopes of Area F, Asphaltic Concrete. Note absence of form lines and cracks.

Table B.1. Slope Analysis of Portland Cement Concrete Areas

Area	Direction of Long Axis From	Direction of Long Axis To	Slope left of ℄ (%)	Slope right of ℄ (%)	Average Slope (%)	Upper Cross Slope (%)	Lower Cross Slope (%)	Av. Cross Slope (%)	Direction of Cross Slope From	Direction of Cross Slope To	Resultant Slope (%)	Direction of Resultant
A-1	South	North	1.05	0.96	1.00	0.05	0.70	0.37	East	West	1.1	20°
A-2	"	"	0.95	0.89	0.92	0.01	0.40	0.20	"	"	0.9	23°
B-1	West	East	0.06	0.09	0.07	0.60	0.90	0.75	South	North	0.8	84°
B-2	"	"	0.16	0.10	0.13	2.60	1.80	2.20	"	"	2.6	80°
C-1	South	North	2.06	2.07	2.06	0.80	0.80	0.80	West	East	1.6	21°
C-2	"	"	2.08	2.06	2.07	0.60	0.40	0.50	"	"	2.2	14°
C-3	"	"	2.05	2.10	2.08	0.50	1.05	0.78	"	"	2.2	20°
C-4	"	"	1.91	2.03	1.97	0.60	1.80	1.20	"	"	2.3	31°
C-5	"	"	2.04	2.07	2.05	0.70	1.05	0.87	"	"	2.2	23°
D-1	"	"	4.10	2.18	3.14	4.11	1.02	2.56	West	East	4.0	39°
D-2	"	"	4.86	2.17	3.53	0.45	3.12	1.68	"	"	3.5	25°
D-3	"	"	3.75	3.51	3.63	0.73	0.38	0.55	"	"	2.2	9°
D-4	"	"	2.06	2.01	2.03	0.91	0.84	0.88	"	"	2.3	23°
D-5	"	"	2.24	2.24	2.24	0.82	0.82	0.82	"	"	1.9	20°
D-6	"	"	2.13	1.69	1.91	0.68	0.02	0.33	"	"	2.6	10°
D-7	"	"	2.30	2.21	2.25	1.02	2.13	1.52	"	"	2.1	34°
D-8	"	"	2.01	1.93	1.97	0.77	0.66	0.72	"	"	1.7	36°
D-9	West	East	1.57	1.21	1.39	.90	2.7	0.90	South	North	1.0	33°
E-1	"	"	.60	.57	0.58	0.70	1.00	0.85	"	"	1.2	82°
E-2	"	"	.74	.21	0.47	.90	1.30	1.10	"	"	2.3	77°

Table B.2. Slope Analysis of Asphaltic Concrete Areas

Area	Direction of Long Axis From	To	Slope left of ℄ (%)	Slope right of ℄ (%)	Average Slope (%)	Upper Cross Slope (%)	Lower Cross Slope (%)	Av. Cross Slope (%)	Direction of Cross Slope From	To	Resultant Slope (%)	Direction of resultant slope (degree)
F-1	South	North	2.02	1.92	1.97	1.75	0.75	1.25	West	East	2.4	32
F-2	"	"	2.01	2.00	2.00	1.35	1.25	1.30	"	"	3.0	33
F-3	"	"	2.20	2.07	2.13	2.75	1.50	2.12	"	"	1.5	45
F-4	"	"	2.05	2.02	2.04	1.25	1.00	1.12	"	"	2.3	29
F-5	"	"	1.87	2.05	1.96	1.25	2.00	1.62	"	"	2.5	40
F-6	"	"	2.07	2.10	2.08	0.50	0.75	0.62	"	"	2.2	17
F-7	"	"	2.12	2.02	2.07	1.00	0.00	0.50	"	"	2.1	14
F-8	"	"	2.15	2.13	2.14	1.00	0.85	0.92	"	"	2.3	23
F-9	"	"	2.12	2.27	2.20	0.00	1.00	0.50	"	"	2.2	13
F-10	"	"	2.35	2.42	2.38	0.75	1.50	1.00	"	"	2.6	23
F-11	"	"	2.52	2.61	2.56	0.65	1.50	1.58	"	"	3.0	32
F-12	"	"	2.62	2.55	2.58	1.50	0.75	0.50	"	"	2.6	11
G-1	"	"	1.21	0.71	0.96	Roadways' Crowned-Not Applicable					1.0	
G-2	"	"	1.93	1.94	1.94	"					1.9	
G-3	"	"	1.12	1.20	1.16	"					1.2	
G-4	"	"	0.64	1.15	0.90	"					0.9	
H-1	"	"	1.15	1.11	1.13	"					1.1	
H-2	"	"	0.52	1.05	0.76	"					0.8	
H-3	"	"	1.17	1.11	1.14	"					1.1	
H-4	"	"	1.43	0.56	1.00	"					1.0	
J	West	East	0.19	0.43	0.31	1.80	1.20	1.50	North	South	1.6	78

Run-off from Area E was led by a dike north of Area E-1 into a sump east of the E Area.

Dikes between each of the F areas prevented run-off spreading from area to area, and led into a large drainage ditch.

To accomodate the run-off from each of the G and H areas, the drainage ditches along the sides of the streets were cleared of weeds and rubbish and in some cases deepened. As each area was to be used in testing, a "V" shaped (plan view) dike was placed at the down slope end of the area to channel the water into the ditches and to prevent contamination of test areas down the slope. The drainage ditches adjacent to the roads were deep enough and had a shallow enough slope to allow them to be used as sumps.

The soil throughout the Camp Stoneman site was a "hardpan" type clay and the seepage of moisture into the soil was slow, allowing the run-off to stand in the sump areas without danger of rapid seepage into the water table.

B.3 SURFACE CONDITIONS - ROOFING AREAS

A description of the roofing surfaces together with details of arrangement is presented in Table B.3. The only surfaces on existing buildings, tar and gravel and composition shingles, had been exposed to the weather for seven years, the composition shingles for six years.

All other roofing surfaces had to be fabricated from new materials. Test panels (see Fig. B.5) were constructed and placed on a 12 x 16-ft supporting framework to simulate roof slope. The size was assumed to be large enough to allow proper evaluation of operating rates.

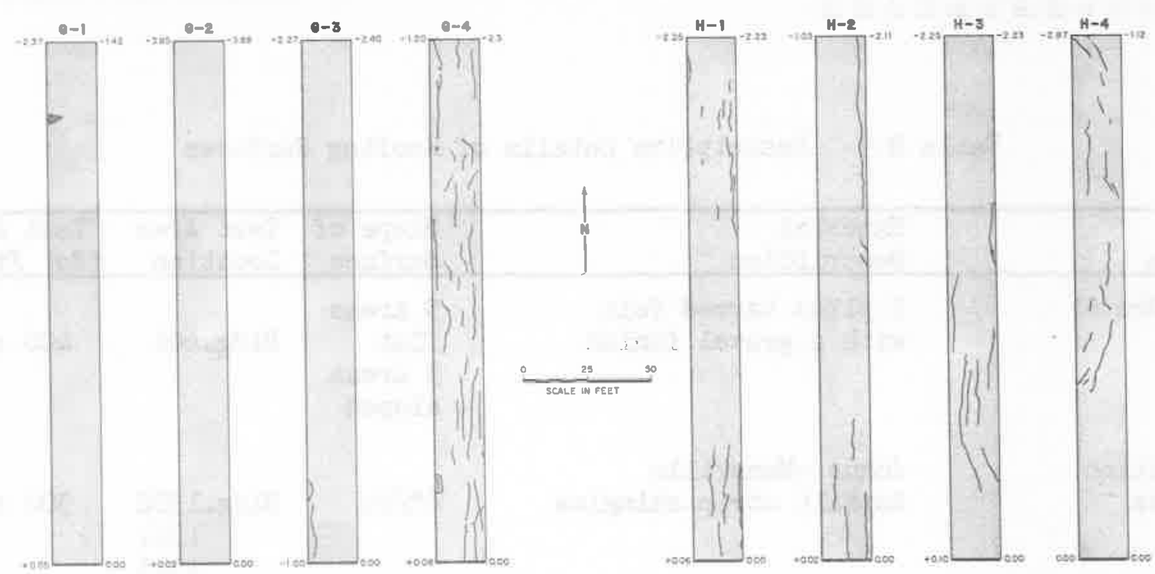


Fig. B.4 Slopes, Cracks, and Spalling in Areas G and H, Asphaltic Concrete Roadways.

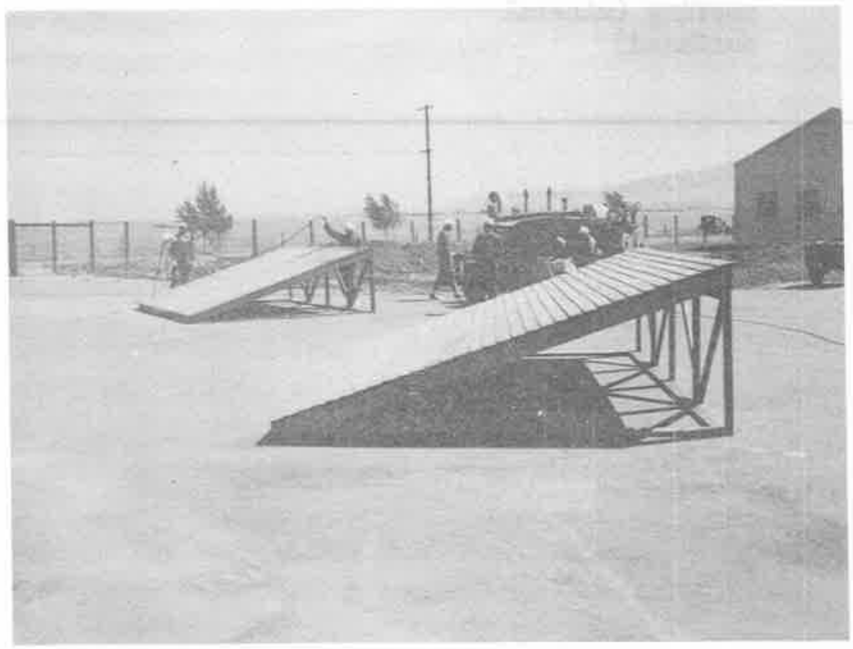


Fig. B.5 Test Panels of Roofing Materials.

Table B-3 Descriptive Details of Roofing Surfaces

Test Surface	Material Description	Slope of Surface	Test Area Location	Test Area (Sq. Ft.)
Tar & Gravel	5 plies tarred felt with a gravel finish	9 areas flat 3 areas sloped	Bldg.601	400 each
Composition Shingles	Johns-Mansville Asphalt strip shingles	6"/ft	Bldg.1302 1311 1315 1328	300 each
Wood Shingles	No.1 Red Cedar Shingles	4"/ft	Panels	192
Corrugated Steel	Corrugated galvanized steel sheets (27-1/2" x 144" x 22 GA)	4"/ft	Panels	192
Asphalt Roll Roofing	80# asphalt roll roofing (mineral surfaced)	4"/ft	Panels	192

APPENDIX C

PETROGRAPHIC REPORT AND CHEMICAL ANALYSIS CAMP STONEMAN EARTH AND SAN FRANCISCO BAY MUD SAMPLES*

C.1 SAMPLES

Four samples of Camp Stoneman earth and one composite sample of San Francisco Bay mud were received for petrographic and chemical testing for the U.S. Naval Radiological Defense Laboratory. These samples were numbered as follows:

U. S. Navy	Pile #1, Camp Stoneman	12048-0
U. S. Navy	Pile #2, Camp Stoneman	12049-0
U. S. Navy	Pile #3, Camp Stoneman	12050-0
U. S. Navy	Pile #4, Camp Stoneman	12051-0
U. S. Navy	Bay Mud	12052-0 to 12055-0

C.2 PETROGRAPHIC EXAMINATION

C.2.1 Test Procedure

Camp Stoneman Earth

Representative portions of each of the four samples were thoroughly mixed together forming a composite. This composite sample was examined megascopically and with the low power microscope. A weighed portion of the composite sample was washed through the No. 4, No. 8, No. 16, No. 30, No. 50, No. 100 and No. 200 standard size sieves to remove all clay and silt from the coarser particles for better identification. The retained material was then oven dried and weighed. The various weights were tabulated and converted to percentage quantities. Identification of rock and mineral types was made of particles retained on the various sieves with the use of the microscope. The fine material passing the No. 200 sieve was tested for montmorillonite. A trace quantity of montmorillonite was found in the composite sample.

*Extracted from report submitted by South Pacific Division Laboratory, Corps of Engineers, U.S. Army, Sausalito, California.

TABLE C.1 Camp Stoneman Earth Samples

Petrographic Summary

COMPOSITE - Sample No. 12048-0, Pile #1; No. 12049-0, Pile #2; No. 12050-0, Pile #3; No. 12051-0, Pile #4

Sieve Size	Weight	Percent Retained	Cumulative % Passing
#4	-	-	100
#8	0.25 g	0.3	99.7
#16	0.50	0.5	99.2
#30	0.80	0.8	98.4
#50	3.80	3.8	94.6
#100	10.25	10.3	84.3
#200	10.00	10.0	74.3
Pan	74.40	74.3	0
	100.00 g	100.0	

Bay Mud

A portion of the sample was washed through the No. 200 sieve and the retained material dried and examined with the microscope. The material passing the No. 200 sieve was placed in an oven and dried. This material was also examined, using the petrographic microscope. No identification of the finer particles could be made with the microscope, except that a considerable portion of the fines were of a crystalline nature. A portion of the fines was tested with benzidine to determine the presence or absence of montmorillonite. A considerable portion of the fine material proved to be of the montimorillonite type of clay.

C.3 PETROGRAPHIC SUMMARY

C.3.1 Camp Stoneman Earth

The composited Camp Stoneman sample was found to consist of sub-angular particles of various rock and mineral types coarser than the No. 200 sieve and silt and clay finer than the No. 200. The rock types were identified as brown and tan shale, volcanic tuff and basalt, calcareous sandstone, jasperoid chert and basic igneous. The mineral constituents are largely sub-round quartz and feldspar with lesser quantities of iron oxide, amphibole, pyroxene and biotite. A small amount of montmorillonite was detected in the material passing the No. 200 sieve by using the benzidine test. The weight and percentage of the various size particles of the Camp Stoneman composite earth sample are shown on Table C.1. Table C.2 shows the various rock and mineral types with their percentage of occurrence in the various sieve sizes and their weighted average percentage in the composite sample.

C.3.2 Bay Mud

The sample consisted largely of silt, clay and organic matter. Several mineral types were found retained above the No. 200 sieve, which consisted largely of rounded quartz and feldspar grains, iron oxides and thin flakes of biotite. Montmorillonite was found in the finer material passing the No. 200 sieve. The organic matter consists largely of shell fragments, with some vegetable matter. Table C.3 shows the particle identification of material retained on the No. 200 sieve of the bay mud sample.

C.4 CHEMICAL ANALYSIS

A standard oxide analysis was made on each composite sample and as the sums of the ingredients were near 100 percent no search was made for minor constituents. Carbon dioxide and chloride were reported separately as they are included in the loss on ignition test. Bound-water, chemical water and

TABLE C.2 Camp Stoneman Earth Samples

COMPOSITE OF SAMPLES NOS., 12048-0, Pile No. 1;
12049-0, Pile No. 2; 12050-0, Pile No. 3; 12051-0, Pile No. 4.

Sieve Size:	#8		#16		#30		#50		#100		#200		Total Wtd.	
% Retained:	0.3		0.5		0.8		3.8		10.3		10.0		Percent	
	%	Wtd. %	%	Wtd. %	%	Wtd. %	%	Wtd. %	%	Wtd. %	%	Wtd. %		Calculated to 100%
Rock Types														
Shale	12	0.04	32	0.1	3	Tr.	4	0.2	-	-	-	-	0.3	1.2
Volcanic	88	0.26	15	0.1	33	0.3	13	0.4	17	1.8	28	2.8	5.7	22.2
Calcareous Sandstone	-	-	36	0.2	22	0.2	10	0.3	9	0.9	10	1.0	2.6	10.1
Chert	-	-	1	Tr.	4	Tr.	4	0.2	3	0.3	2	0.2	0.7	2.7
Basic Igneous	-	-	1	Tr.	1	Tr.	Tr.	0.1	5	0.5	5	0.5	1.1	4.3
Mineral Types														
Quartz	-	-	15	0.1	29	0.2	35	1.3	32	3.3	26	2.6	7.5	29.2
Feldspar	-	-	-	-	7	0.1	24	0.9	22	2.3	20	2.0	5.3	20.6
Magnetite	-	-	-	-	-	-	2	0.1	2	0.2	3	0.3	0.6	2.3
Amphibole	-	-	-	-	-	-	2	0.1	4	0.4	1	0.1	0.6	2.3
Pyroxene	-	-	-	-	-	-	Tr.	Tr.	4	0.4	1	0.1	0.5	1.9
Biotite	-	-	-	-	1	Tr.	2	0.1	1	0.1	2	0.2	0.4	1.6
Hematite	-	-	-	-	-	-	2	0.1	1	0.1	2	0.2	0.4	1.6
Totals	100	0.3	100	0.5	100	0.8	100	3.8	100	10.3	100	10.0	25.7	100.0

TABLE C.3 Bay Mud Composite of Samples

Nos. 12052-0, 12053-0, 12054-0 and 12055-0

Material Retained on No. 200 Sieve

Organic

Shell Fragments	- White and dark blue shell material
Vegetative	- Seaweed, wood fragments

Mineral

Quartz	- Fine rounded to angular particles of transparent quartz
Feldspar	- Angular particles of weathered feldspar
Mica	- Thin, fragile plates of yellow and brown biotite
Iron Oxides	- Black particles of magnetite and hematite

Material Passing the No. 200 Sieve

The fine material passing the No. 200 sieve is largely silt and clay. This material gave a positive test for presence of montmorillonite.

organic matter are also included in the loss on ignition. Table C.4 shows the results of the tests in detail.

C.5 SOIL TEST SUMMARY

Table C.5 show the results of the soil tests accomplished on the raw and processed bulk carrier materials.

TABLE C.4 Chemical Analysis

	Composite Camp Stoneman Earth	Composite of Bay Mud
Oxide Analysis		
Loss on Ignition, %	4.83	8.06[a]
Silica (SiO_2), %	64.43	57.74
Aluminum Oxide (Al_2O_3), %	16.29	15.18
Ferric Oxide (Fe_2O_3), %	4.89	6.19
Calcium Oxide (CaO), %	2.49	2.94
Magnesium Oxide (MgO), %	3.23	1.68
Sulfur Trioxide (SO_3), %	0.05	2.56
Sodium Oxide (Na_2O), %	1.70	2.88
Potassium Oxide (K_2O), %	2.47	3.08
Carbon Dioxide (CO_2), %	0.56	1.35
Water Soluble Chloride (Cl), %	0.04	1.48

(a) Corrected for loss of alkali by volatilization of Sodium Chloride. Actual loss was 9.02%.

NOTE: Other elements may be present in trace amounts only. All results are based on oven dry weight of samples.

TABLE C.5 Soil Test Result Summary

Laboratory Descriptive Classification	Mechanical Analysis - % Finer: Gravel #4	Sand #10	Sand #40	Sand #60	Silt or Clay #200	Liquid Limit	Plasticity Index	Specific Gravity +4	Specific Gravity -4
Raw Camp Stoneman Soil									
Sandy Clay		100	98	94	81	46	29		
Sancy Clay		100	97	92	76	46	28		2.68
Sandy Clay	100	99	96	88	68	39	23		
Sandy Clay	100	99	96	90	72	40	26		
Processed Camp Stoneman Soil									
Sandy Clay		100	99	91	68	42	29		
Sandy Clay		100	99	93	75	39	27		
Sandy Clay		100	99	94	74	46	32		
Sandy Clay		100	99	93	75	43	29		
Sandy Clay			100	96	71	42	29		
Raw Bay Mud									
Clay (CH)	100	99	98	98	91	58	32		2.70
Clay (CH)	100	99	98	97	89	55	34		
Sandy Clay[a]	100	98	96	92	83	54	29		
Sandy Clay	100	98	96	94	84	51	29		
Processed Bay Mud									
Silty Clay			100	97	90	48	22		
Silty Clay[b]		100	99	96	80	41	16		
Clay (CH)		100	99	97	88	53	29		
Clay (CL)			100	98	89	43	20		
Sandy Clay		100	99	97	81	55	31		
Processed Camp Stoneman Soil									
Sandy Clay[c]		100	98	94	81	-	-		

(a) Approximate shell content in sand sizes, 5% by weight.
(b) Approximate shell content in sand sizes, 3% by weight.
(c) Special Hydrometer test with 1-hour stirring time.

APPENDIX D

LAYOUT OF ROOF AREAS

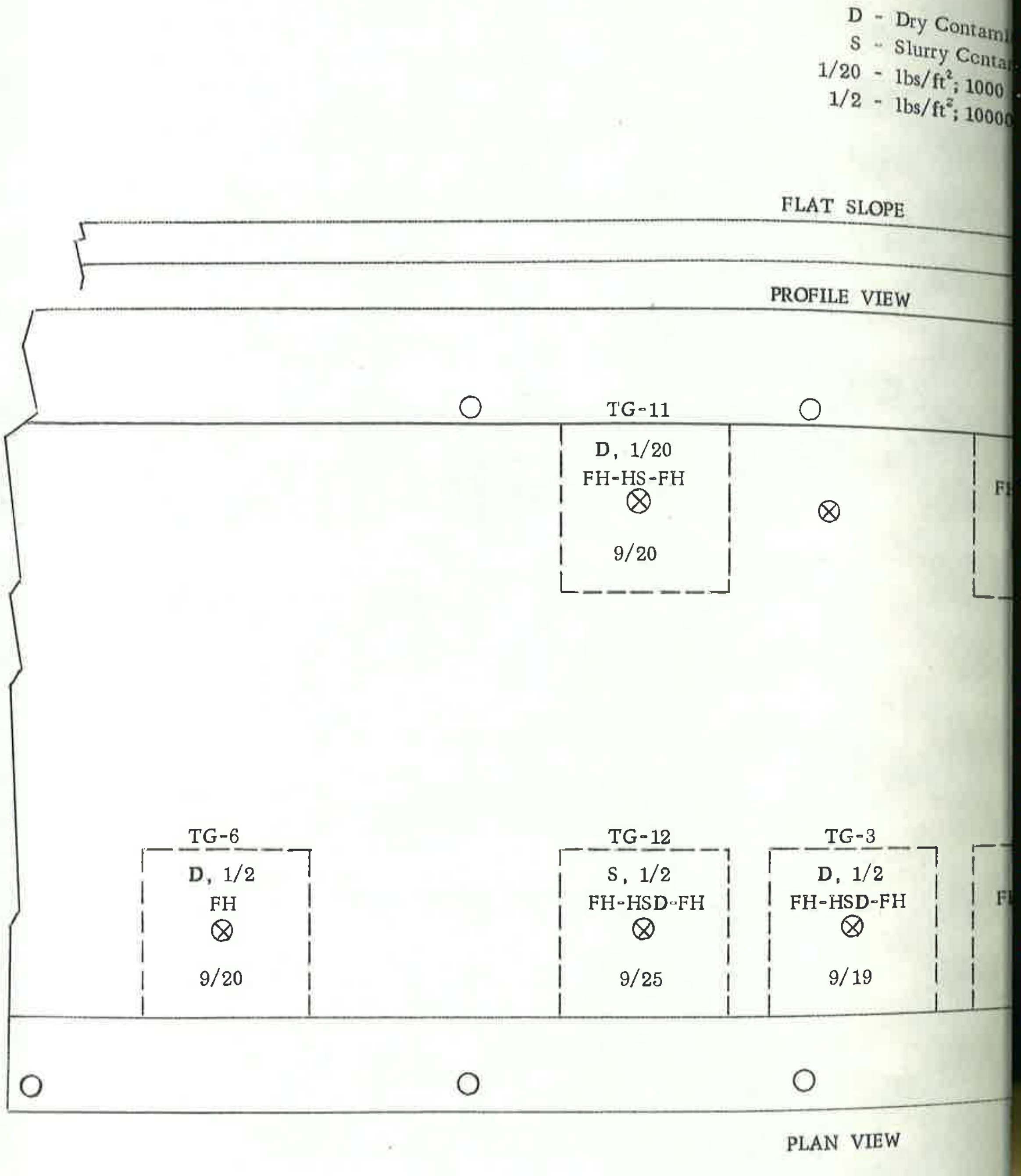
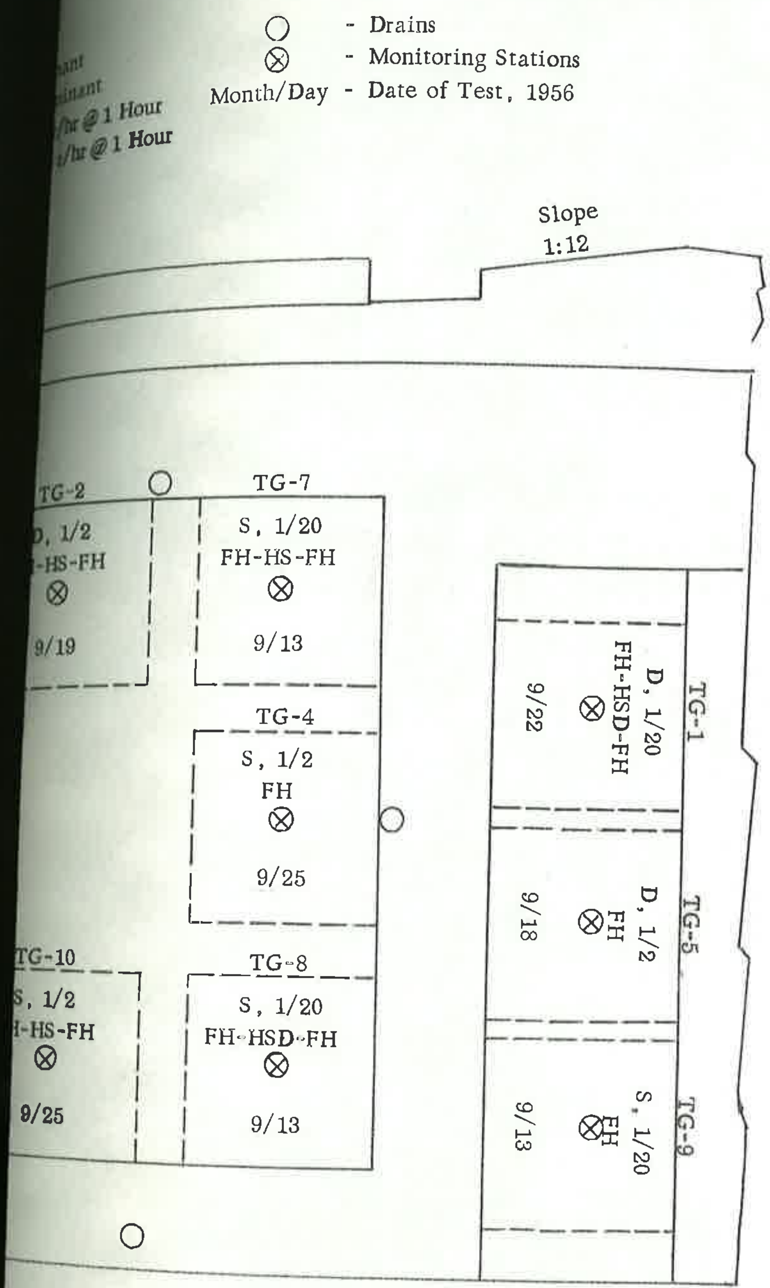


Fig. D.1 Layout of Tar and Gravel R



oof Test Areas

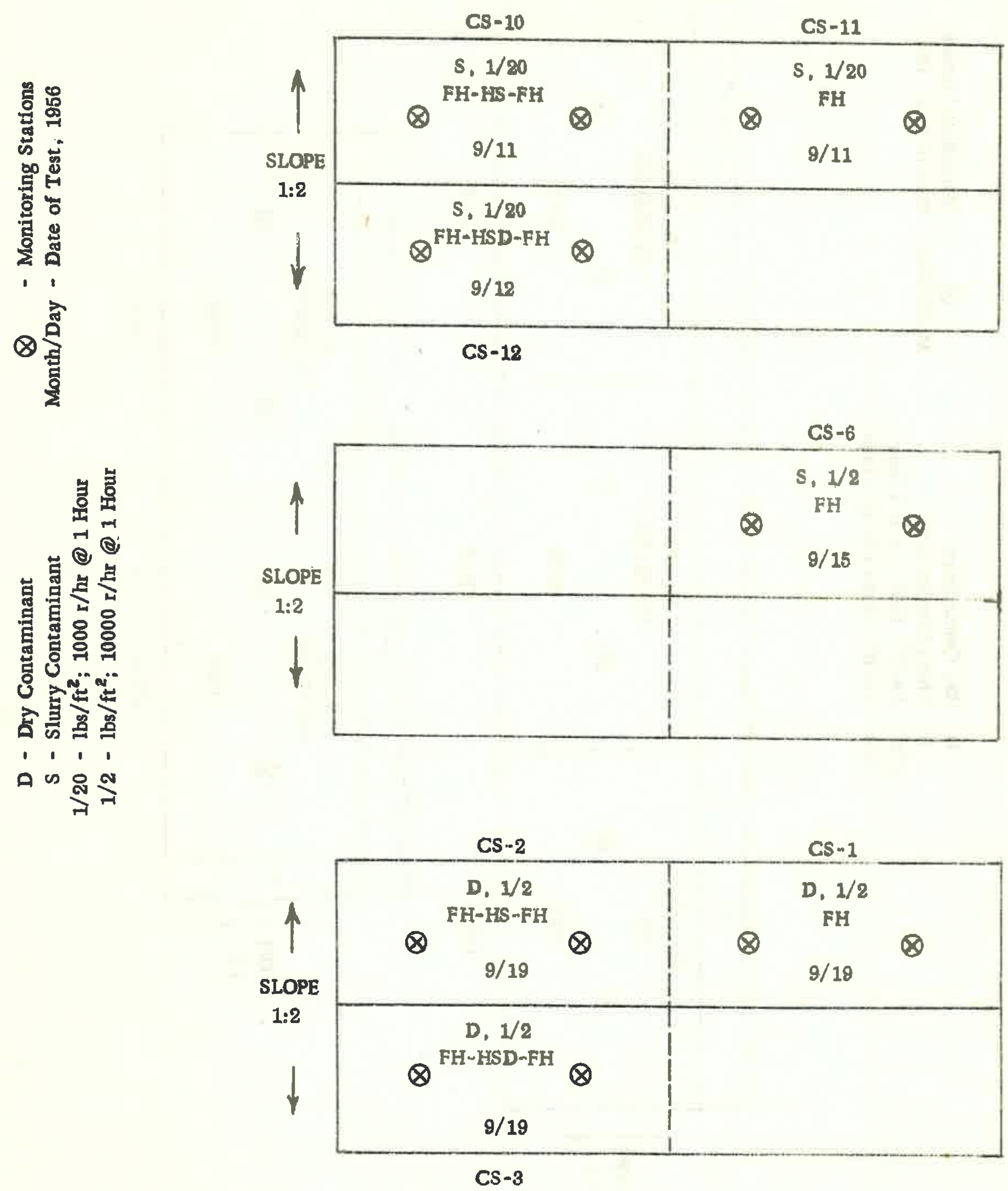


Fig. D.2 Layout of Composition Shingle Roof Test Areas

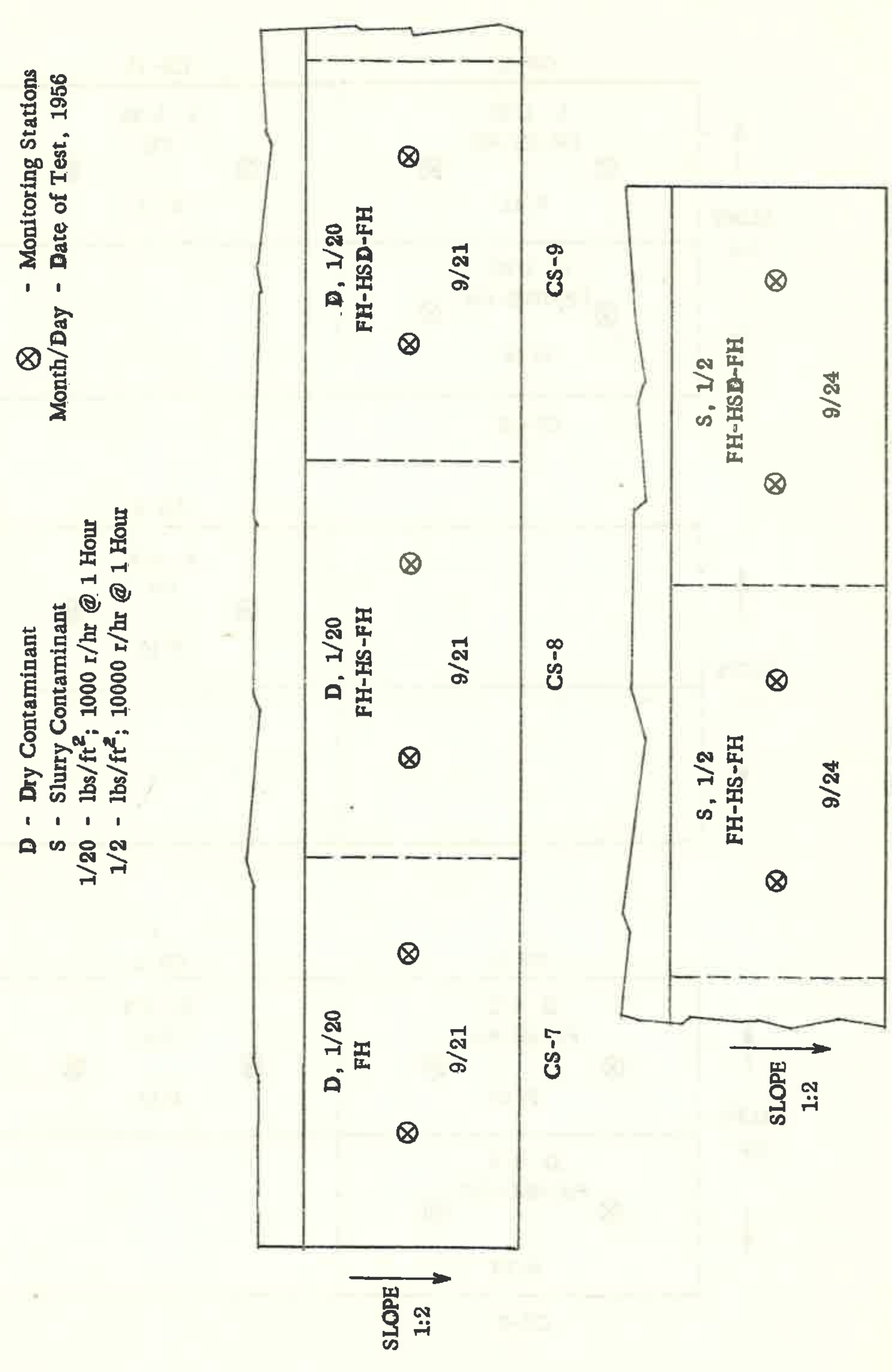


Fig. D.3 Layout of Composition Shingle Roof Test Areas

APPENDIX E

COST OF EQUIPMENT PER TEAM

Table E.1

Method	Item	Units	Unit Cost	Paved Area No. Req.	Paved Area Cost	Roofs No. Req.	Roofs Cost
FH	Firehose, 2-1/2"	50 ft	37.50	3	112.50	3	112.50
	Firehose, 1-1/2"	50 ft	18.90	6	113.40	6	113.40
	Wye gate, 2-1/2-1-1/2 - 1-1/2	ea.	27.50	1	27.50		
	500 GPM Defense pump	ea.	2150.00	1/2	1075.00	1/4	537.50
	Fog nozzles	ea.	49.00	2	98.00	1	49.00
					$1426.40		$812.40
FH-HSD-FH	Scrub Brush	ea.	.70	4	2.80	3	2.10
	Galv. Bucket 2 gal.	ea.	1.00	1	1.00	1	1.00
MF	Street Flusher	ea.	~10,000.00	1	~10,000.00		
	Firehose, 2-1/2"	50 ft	37.50	1	37.50		
					~10,037.50		
MS	Street Flusher	ea.	~10,000.00	1	~10,000.00		

APPENDIX F

SPECIFIC ACTIVITY AND SURFACE DENSITY OF DEPOSITED SYNTHETIC FALLOUT

Table F.1 presents the mean surface density in grams per square foot, plus or minus one standard deviation, of simulant deposited for each test and the mean specific activity on each test in microcuries per gram, plus or minus one standard deviation. Absence of the standard deviation figure in the table indicates that less than three samples were taken.

The soil collected in 1-ft square sample pans, which had been set out on each test area before the simulant was dispersed, was weighed to determine the mass of simulant dispersed. The samples of slurry-type contaminant were dried before weighing. The specific activity of the simulant was determined by weighing an aliquot of each surface density sample and counting it in a 4-π ion chamber.

The readings taken from the 4-π ion chamber were in milliamperes. The conversion to microcuries was made by the following relation, based on calibration with samples from the National Bureau of Standards:

$$\mu c = \frac{ma}{8.13 \times 10^{-9}}$$

Table F.1 Specific Activity and Surface Density of Synthetic Fallout

Capsule	Date Broken (Sept.'56)	No. of Pans	Area	Surface	Mean Density g/ft² ± Std Dev	Type of contaminant	Date	Mean Specific Activity (μc/g ± Std Dev.)
1	3	3	A-1	PC	29 ± 20	Dry	-	-
		3	F-1	AC	14 ± 5		-	-
		1		RR	8		-	-
2	4	3	C-1	PC	17 ± 9		5 Sep	-
		3	G-1	AC	18 ± 13			1.08±.92
		1(plate)		GR	38			.695
		"		WS	32			.997
		"		RR	26			1.10
3,4	5	3	D-1	PC	263 ± 51		6 Sep	2.05±.01
		3	F-12	AC	305 ± 16			1.92±.01
		1(plate)		GR	105			2.02
		"		WS	110			1.92
		"		RR	164			1.94
5	9	6	H-1	PC	221 ± 31		10 Sep	1.43±.18
		3	F-11	AC	226 ± 22			1.70±.12
6[1]	10	8	D-7	PC	36 ± 9	Slurry	11 Sep	2.88±.65
		8	G-2	AC	25 ± 5			3.17±.34
		4	Bldg.1302	CS	26 ± 7			4.74±.27
7	11	8	C-5	PC	24 ± 7		12 Sep	8.11±.76
		8	F-10	AC	12 ± 4			8.36±1.1
		2		GR	14			8.22
		2		WS	27			8.12
		2		RR	22			8.70
8	12	8	A-2	PC	18 ± 5		13 Sep	7.26±.22
		8	F-2	AC	22 ± 2			7.33±.11
		3	Bldg.601	T&G	17 ± 3			7.33±.07
9	13	14	D-5	PC	78 ± 6		14 Sep	3.12±.04
		6	H-2	AC	83 ± 14			3.09±.05
		1		GR	213			3.12
		1		WS	187			3.08
		1		RR	155			3.20
10	14	8	E-1	PC	120 ± 22		15 Sep	3.63±.10
		6	F-9	AC	113 ± 43			3.46±.02
		2	Bldg.1311	CS	116			2.31
11	16	12	C-4	PC	172 ± 26	Dry	17 Sep	2.46±.11
		9	G-3	AC	159 ± 16			2.44±.06
		1		GR	118			2.56
		1		WS	142			2.53
		1		RR	131			2.56

Table F.1 Specific Activity and Surface Density of Synthetic Fallout (Cont'd)

Capsule	Date Broken Sept'56	No. of Pans	Area	Surface	Mean Density $g/ft^2 \pm$ Std. Dev	Type of contaminant	Date	Mean Specific Activity $\mu c/g \pm$ Std Dev
12	17	9	D-9	PC	262±50	Dry	18 Sep	1.27±.04
		7	H-3	AC	238±41			1.29±.02
		2	Bldg.601	T&G	173			1.24
13	18	6	D-3	PC	211±25		19 Sep	.921±.02
		9	E-2	PC	205±27			.919±.02
		3	Bldg.1315	CS	180±119			.958±.02
		4	Bldg.601	T&G	194±52			.938±.02
14	19	9	C-3	PC	64±34		20 Sep	1.32±.29
		9	G-4	AC	41±21			1.62±.18
		1		GR	23			.908
		1		WS	27			1.06
		1		RR	31			.873
15	20	6	D-8	PC	23±6		21 Sep	5.60±1.2
		9	F-8	AC	40±18			5.38±1.1
		1		GR	19			5.46
		1		WS	13			5.95
		1		RR	17			6.59
		3	Bldg.1328	CS	27±5			5.86±1.1
16	21	9	A-1	PC	34±12		22 Sep	5.76±.34
		9	H-4	AC	31±15			5.67±.59
		1		GR	37			5.36
		1		WS	32			5.76
		1		RR	24			5.09
		1	Bldg.601	T&G	33			4.53
17	23	9	C-2	PC	86±13	Slurry	24 Sep	3.27±.04
		9	F-3	AC	98±15			3.27±.07
		1		GR	121			3.30
		1		WS	165			3.47
		1		RR	208			3.32
		2	Bldg.1328	CS	140			3.161
18	24	8	D-4	PC	103±11		25 Sep	1.99±.09
		9	F-7	AC	104±13			2.09±.04
		3	Bldg.601	T&G	102±14			1.78±.12
		1		GR	131			1.76
		1		WS	124			1.78
		1		RR	162			1.67
19	25	8	D-2	PC	38±3		26 Sep	7.21±.05
		8	F-6	AC	42±10			7.39±.09
		1		GR	12			7.55
		1		WS	18			7.38
		1		RR	54			7.55

51	The Quartermaster General
52	CG, Chemical Corps Res. and Dev. Command
53	Hq., Chemical Corps Materiel Command
54	President, Chemical Corps Board
55-57	CO, BW Laboratories
58	CO, Chemical Corps Training Command (Library)
59	CO, Chemical Corps Field Requirements Agency
60-61	CO, Chemical Warfare Laboratories
62	Office of Chief Signal Officer (SIGRD-8B)
63	CG, Continental Army Command, Fort Monroe (ATDEV-1)
64	CG, Quartermaster Res. and Eng. Command
65	CO, Army Artillery & Guided Missile Section, Fort Sill
66	Director, Operations Research Office (Librarian)
67	CO, Dugway Proving Ground
68-70	CG, Sixth U.S. Army, Presidio, San Francisco
71	CG, Engineer Res. and Dev. Lab. (Library)
72	CO, Transportation Res. and Dev. Command, Fort Eustis
73	President, Board No. 6, CONARC, Fort Rucker
74	NLO, CONARC, Fort Monroe
75	Director, Office of Special Weapons Development, Fort Bliss
76	CO, Ordnance Materials Research Office, Watertown
77	CG, Redstone Arsenal

AIR FORCE

78	Directorate of Intelligence (AFOIN-3B)
79	Commander, Air Materiel Command (MCMTM)
80	Commander, Wright Air Development Center (WCRTY)
81	Commander, Wright Air Development Center (WCRTH-1)
82	Commander, Air Res. and Dev. Command (RDTDA)
83	Commander, Air Res. and Dev. Command (RDTWA)
84	Directorate of Installations (AFOIE-ES)
85	Director, USAF Project RAND (WEAPD)
86	CG, Strategic Air Command (Operations Analysis Office)
87-88	Commander, Special Weapons Center, Kirtland AFB
89	Director, Air University Library, Maxwell AFB
90-91	Commander, Technical Training Wing, 3415th TTG
92	CG, Cambridge Research Center (CRZT)
93	AFOAT - Headquarters

OTHER DOD ACTIVITIES

94	Chief, Armed Forces Special Weapons Project
95	AFSWP, SWTG, Sandia Base
96-98	AFSWP, Hq., Field Command, Sandia Base
99	Assistant Secretary of Defense (Res. and Dev.)
100-101	Assistant Secretary of Defense (Civil Defense Div.)
102-106	Armed Services Technical Information Agency

AEC ACTIVITIES AND OTHERS

107 AEC, Military Applications Division
108 Los Alamos Scientific Laboratory (Library)
109 Sandia Corporation (Document Room)

USNRDL

110-150 USNRDL, Technical Information Division

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