AD 424591

UNCLASSIFIED

424591

CATALOGED BY DDC
AS AD NO.

USNRDL-TR-672
18 July 1963

DESIGN CRITERIA FOR ROOF WASHDOWN SYSTEM

Phase 1. Fallout Removal Studies on Typical Roofing Surfaces for Two Size Ranges of Particles (177-350 μ and 350-590 μ)

by
R.H. Heiskell
W.S. Kehrer
N.J. Vella
G. Brown, LCDR, USN (Ret)

U.S. NAVAL RADIOLOGICAL DEFENSE LABORATORY
SAN FRANCISCO · CALIFORNIA · 94135

TECHNICAL DEVELOPMENTS BRANCH
L.H. Gevantman, Acting Head

CHEMICAL TECHNOLOGY DIVISION
L.H. Gevantman, Head

ADMINISTRATIVE INFORMATION

The work reported was part of a project sponsored by the Office of Civil Defense, under Contract No. CDM-SR-59-54. The project is described in USNRDL Technical Program Summary for Fiscal Years 1963, 1964, and 1965, 1 November 1962, where it is designated Problem 2, Program B-3.

AVAILABILITY OF COPIES

Eugene P. Cooper
Eugene P. Cooper
Scientific Director

D. C. Campbell, CAPT USN
Commanding Officer and Director

ABSTRACT

Fallout simulant particles ranging in size from 177 to 350 and 350 to 590 microns were deposited on selected typical roof sections 48 ft long by 8 ft wide to determine the effect of water flow rate, slope, and surface type on washdown effectiveness. More than 90 % of the simulant can be removed on composition shingles, aluminum shingles and roll roofing at slopes of 1:12 or steeper with 2 to 3 gallons of water per min per ft of roof width (gpm/ft). It was found that washdown is ineffective on tar and gravel roofing without prior removal of the loose gravel. Washdown on a fiberglass epoxy laminated roof will remove better than 99 % of the simulant particles with a water flow rate as low as 1 gal/min/ft.

SUMMARY

Problem

To develop design criteria for roof washdown systems for existing and new construction.

Findings

Two size ranges of simulated fallout particles were studied on four typical roofing surfaces and two experimental surfaces. A tar and gravel surface was by far the most difficult surface to wash free of fallout particles. At a slope of 1:12 and a water flow of 8.0 gal/min/ft of roof width 45 % of the fallout remained. With a water flow of 4.0 gal/min/ft 61 % of the fallout was retained.

Of the other 5 surfaces tested, composition shingles showed the highest percentage of residual. A slope of 1:8 or higher and a water flow rate of at least 4 gal/min/ft of width are required on this surface to reduce the residual mass to less than 10 %. These same conditions on the composition roll roofing and the aluminum shingles reduced the residual to 5 % or less. A flow rate of only 2-1/2 to 3 gal/min/ft of width is required on the aluminum shingle at a slope of 1:8 to give, at most, 10 % residual mass and 2 to 2-1/2 gal/min/ft of width on the roll roofing. The fiberglass epoxy laminated roof at a slope of 1:8 was washed clean of all but 1/2 % or less of the fallout with a water flow of only 1 gal/min/ft of width.

CONTENTS

LIST OF FIGURES

FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1 Background

Washdown during a contaminating event as a radiological countermeasure was first developed in this country to minimize the contamination of Naval ships. Basic experiments on a water curtain for ships began in 1950 with tests on foot square painted steel plates.[1] The studies were continued[2,3] until the ship washdown system was successfully developed and proof-tested during Operations Castle,[4] Wigwam,[5] and Redwing.[6]

Washdown was first applied to the removal of simulated land fallout from roof surfaces by Owen in 1953, using fluorescent particles for fallout on five different roofing materials, at two water flow rates and at one slope.[7] These tests indicated that a washdown system could be designed for effective removal of radioactive fallout from roofs.

In 1957 studies[8-12] were begun to define the basic transport characteristics of water films in relation to particle size, water-flow, slope, and roofing surface. Work was also initiated in 1957 on the feasibility and applicability of roof washdown systems.[13] This work, developed some basic requirements for washdown on roofing surfaces such as the water flow required for initial wetting of the surfaces and the minimum flow required to maintain coverage for three test surfaces at two slopes. A cost analysis[13] showed this washdown system would cost only a fraction as much as a concrete roof of sufficient thickness to give the same protection. A basic washdown system was proposed which contained a recirculating water system that would assure washdown protection even if the water supply to a building was cut off by a nuclear detonation.

A small scale apparatus was constructed by Kehrer and Clark in 1958 to study the complete recirculating roof washdown system. Two roofing surfaces 1-1/2 ft wide x 8 ft long were tested at various slopes and one water flow rate using an ambrose clay loam fallout simulant contaminated with lanthanum 140. More than 50 % of this simulant had a particle diameter of less than 74 microns. These tests proved the system was effective in reducing the contamination substantially on both composition shingles and composition roll roofing.

A settling tank in the recirculating system was effective in separating out most of the simulated fallout when the tank was large enough to provide a retention time of 10 minutes, i.e. a volume 10 times the number of gallons per minute flowing into the tank. A filtration unit with a fiberglass mat filter proved very effective in removing the fine particles which passed through the settling tank. The compactness of the equipment, however, influenced the reliability of the results of this experiment because of the high background radiation coming from the fallout disperser. Therefore, it was not possible to conduct a comprehensive study of the many variables involved such as fallout particle size, surface type, slope of the roof and the water flow rate.

A full scale roof washdown test facility was then designed and constructed at Camp Parks, Pleasanton, California to provide the facilities necessary to conduct full scale test to study these relationships.

1.2 Washdown Limitations

Reduction of a building's interior dosage by roof washdown can only be effective when the roof contamination is the dominant source. A building with high mass walls and light roof structure can give adequate protection by removing the roof contamination with an effective washdown system. However, washdown would be of little value on a building with light wall construction when the occupants are required to remain in close proximity to the walls. The protection of such a building structure may be adequate if the occupants are confined to the center of the building which has a large floor area.

In the computation of dosage reduction expected from roof washdown on a specific building structure the contribution from "skyshine" should be included. It is the assumption here that the situation first described is the one to which the results of this report will pertain.

1.3 Objective

To obtain the data required to develop engineering and performance specifications for complete operational roof washdown systems for existing and new construction.

The specific objective of the studies covered by this report is to determine washdown effectiveness in removing fallout particles of specific size ranges from typical roofing surfaces at various slopes and water flow rates.

1.4 Approach

The washdown effectiveness in removing simulated fallout particles from typical roofing surfaces were studied under various conditions to determine the optimum water flow rate and surface slope. Non-radioactive silica particles were used in these studies and the removal effectiveness was determined by gravimetric analytical methods. The test parameters included:

1. Test surfaces: Tempered pressed board, aluminum shingles, composition shingles, fiberglass epoxy laminate, roll roofing, and tar and gravel.

2. Water flow rates: Maximum, 8.0 gal/min/ft of width, minimum, 0.3 gal/min/ft of width.

3. Surface slopes: 1:24 (1 ft vertical to 24 ft horizontal); 1:12; 1:8; 1:6 and 1:4.

4. Fallout simulant particles sizes: Fallout particle size will vary with distance from ground zero so an efficient roof washdown system should be capable of removing all sizes of particles that might occur during a contaminating event. Irregularly shaped river bed silica (sp. gr. 2.63) with rounded corners was chosen for the fallout simulant. To simplify this study the following five particle size ranges were selected:

Fallout Simulant Dia. in Microns	U. S. Bur. of Stds. Sieve No.
590 to 1190	30 to 16
350 to 590	45 to 30
177 to 350	80 to 45
88 to 177	170 to 80
44 to 88	325 to 170

The ranges were selected to cover the sizes of greatest concern in a practical number of fractions. In the selection of these particle ranges, a compromise had to be made between very narrow fractions that would react as one particle size and the ease of separation from commercially available silica sand using standard sieves.

The first and second series of roof washdown tests were conducted on the 177-350 μ and the 350-590 μ particle size ranges and are covered by this report. Sieve analyses of the simulant particles used in these studies are given in Appendix A.

2. TEST EQUIPMENT AND INSTRUMENTATION

2.1 Test Planes

The test surfaces were mounted on two planes, each 24 ft wide x 48 ft long and supported by rigid frames. Each plane could be tilted to any slope from 0 to 1:4 (Fig. 1) by a hydraulic system. Each plane was divided into three sections, forming six areas 8 x 48 ft to accommodate six different roofing materials (Fig. 2 and 3) as follows:

1. Tempered pressed fiberboard (trade name, Masonite).* 1/4 in. x 4 ft x 8-ft sheets were installed with the 8-ft dimension across the width of the plane. The butt joints between the sheets were filled with epoxy resin and sanded to a smooth finish (Fig. 2).

2. Aluminum shingles,** commercial interlocking roofing (Fig. 4).

3. Composition shingles, commercial roofing (Fig. 4).

4. Fiberglass epoxy laminate.*** One sheet of fiberglass was bonded to a plywood base with an epoxy laminating resin. The two-component epoxy resin**** was mixed in equal volumes and worked into the fiberglass with a rubber squeegee. After the sheet was completely saturated and smoothed out it was allowed to cure overnight. The lap joints were then sanded smooth and a brush coat of the resin applied. A black pigment was added to this top coat to make simulant particles easy to see (Fig. 3).

5. Roll roofing. 90-lb mineral paper was applied on a mop-tarred plywood base (Fig. 3).

6. Tar and gravel. 5-ply, 15-lb felt paper was tarred and graveled, approximately 2.3 lb of gravel/ft^2 (Fig. 3).

All roofing surfaces were installed over 3/4-in. exterior grade plywood. The masonite was chosen as a smooth surface for comparative purposes. Later a plastic surface was installed as a practical version

*Manufactured by U.S. Plywood Co.

**Manufactured by Aluminum Lock Shingle Co., Oakland, Calif.

***For simplification and because the finished surface is the epoxy resin, the test surface will be referred to as "plastic" throughout the balance of this report.

****Laminating epoxy resin manufactured by Epoxy Coating Co., South San Francisco, Calif.

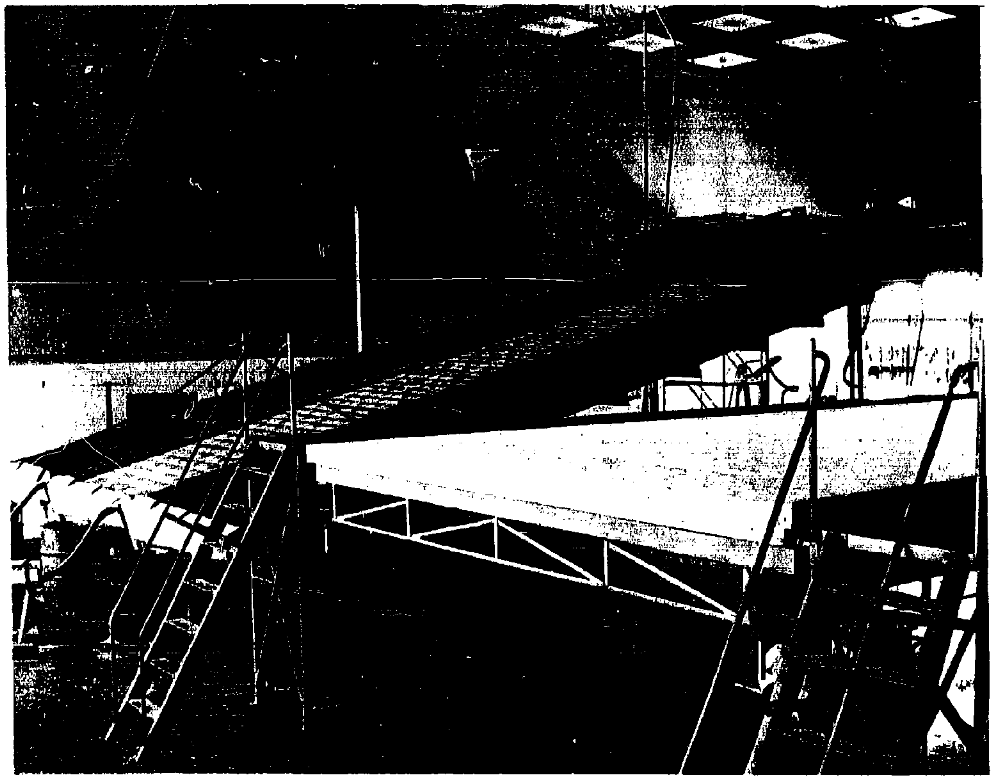


Fig. 1 Test Planes. No. 1 Raised to 1:4 Slope

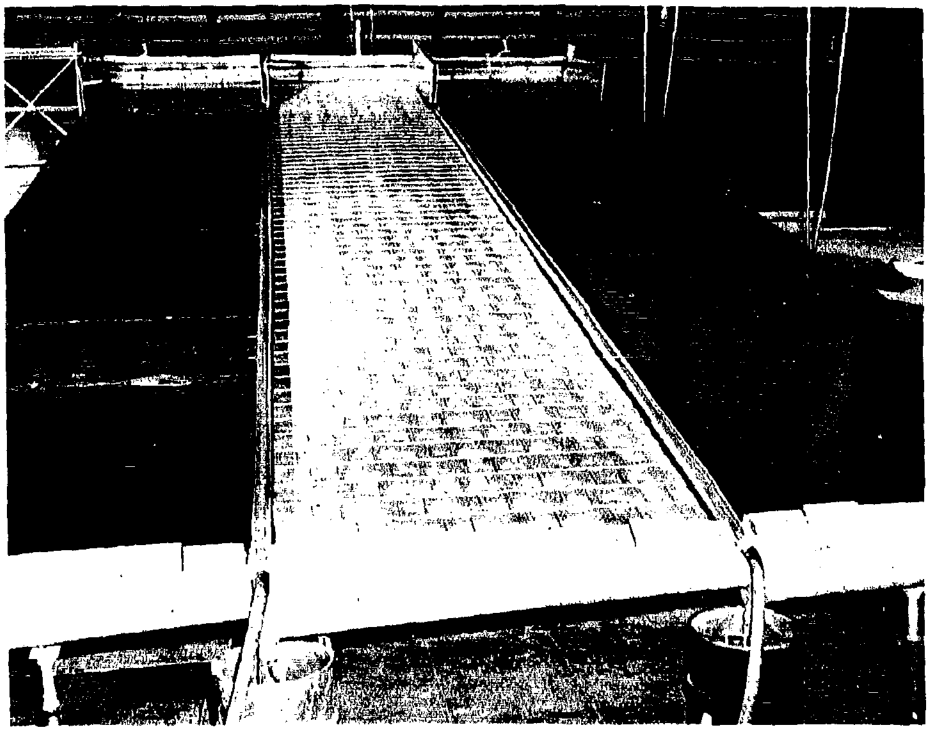


Fig. 2 Test Plane 1 With Surfaces Mounted: Tempered Pressed Board, Aluminum Shingles, and Composition Shingles

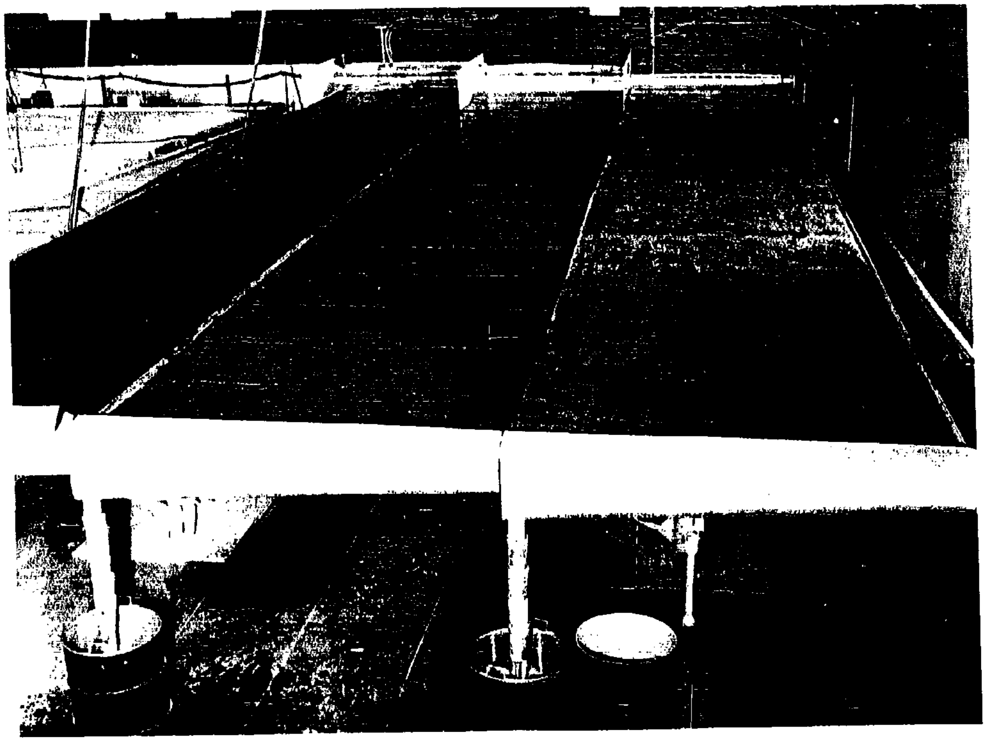


Fig. 3 Test Plane 2 With Surfaces Mounted: Fiberglass Epoxy Resin Laminate (Plastic), Composition Roll Roofing, Tar and Gravel

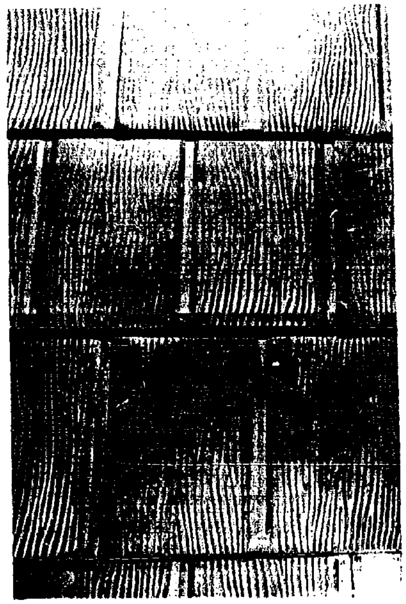
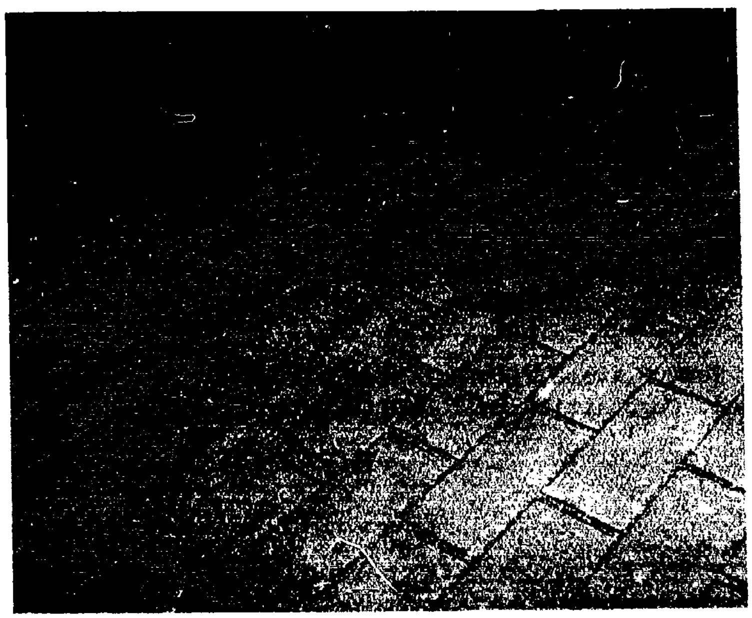


Fig. 4 Test Surfaces.

A. Aluminum Shingles
B. Composition Shingles



of a "near ideal" surface. The standard roofing materials were installed by roofing contractors using the same standard procedures insofar as the special construction of the test planes would permit.

2.2 The Water System

A recirculating water system was used in these tests. This system consisted of a settling and filtration tank and piping for returning the water to the test surfaces (Fig. 5). The tank for each surface was 4-1/2 ft wide x 5 ft high x 10 ft long, with a capacity of about 1350 gal. These were designed to hold two banks of filters, each consisting of 4 commercial 2 x 2-ft air filters with 3/16-in. thick fiberglass filter media* folded in an accordion pleat design to give 25 ft^2 of filter surface area. It was found during preliminary tests that only one bank of 4 filters is needed to remove the particle sizes covered by this report. These filters were needed only during the periods of preparation for the runs and during the clean-up period after a test run because the fallout was caught in the sieves during the test runs.

The washdown water was pumped from the tanks to headers which were 1-1/2-in. pipes located across the 8-ft width at the top of each test surface. These headers, identical for all test surfaces, were mounted about 6-in. above the planes and were provided with fittings to accommodate 2, 4 or 8 nozzles (on 4-ft, 2-ft, or 1-ft spacings).

Flooding type nozzles** were used to create a continuous film of water on the surface (Fig. 6). The water pressure was measured by pressure gauges in the headers. The water flow rate was determined from pressure-volume charts obtained by calibration runs on each surface.

The washdown water for the tar and gravel surface only, flowed first into a 1 x 1-1/2 x 8-ft stilling basin mounted on the upper end of the plane, then flowed (not sprayed) onto the tar and gravel surface. This eliminated the piling up of loose gravel by the high velocity streams, and the hindrance of flow down the plane.

2.3 Fallout Disperser

A fallout dispersal system was designed to deposit continuously a uniformly distributed layer of fallout over the test surface. The system consisted of 88 individual dispersers mounted on the ceiling of the building (Figs. 7 and 8) 24 ft above the planes when they were in the horizontal position. During operation, a continuously metered amount

*Airmat G, manufactured by American Air Filter Co.
**"K" series, manufactured by Spraying Systems, Inc.

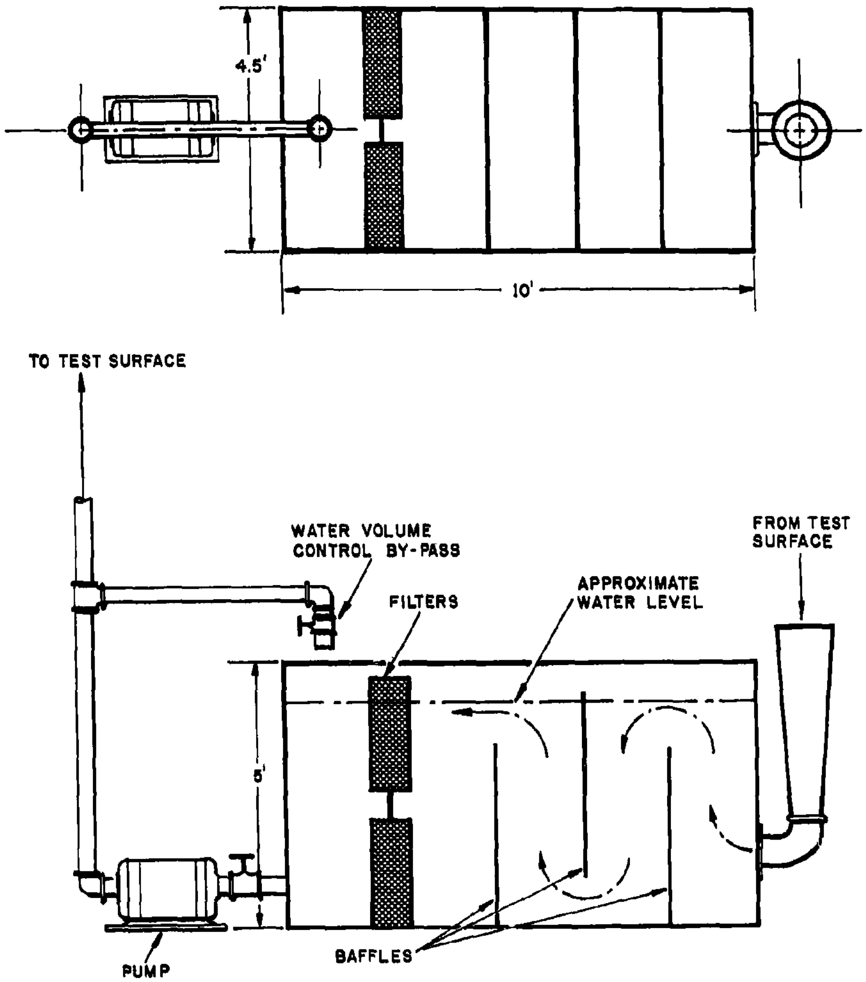


Fig. 5 General Arrangement of Settling and Filtration Tank

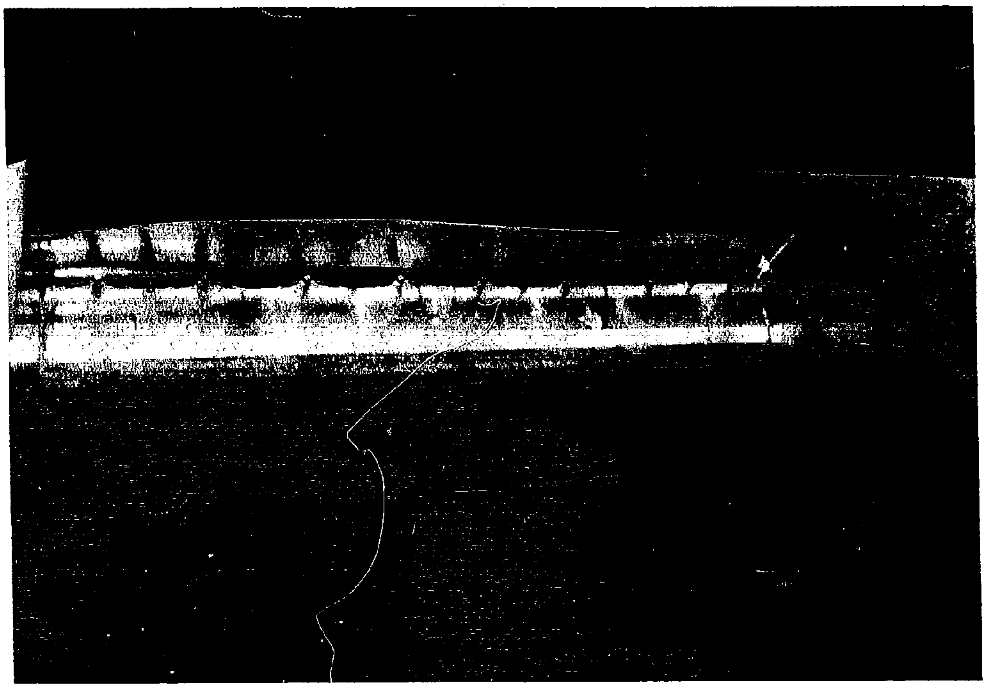


Fig. 6 Water Manifold at Top of Roll Roofing Test Surface

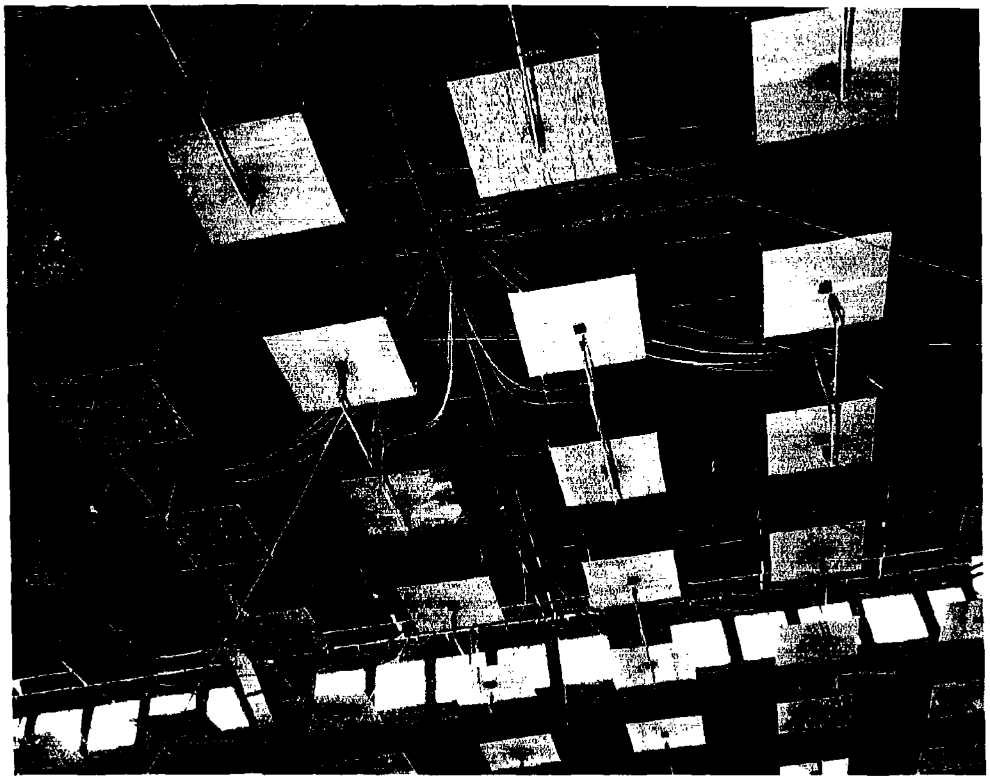


Fig. 7 Fallout Dispersers Mounted Above the Test Planes

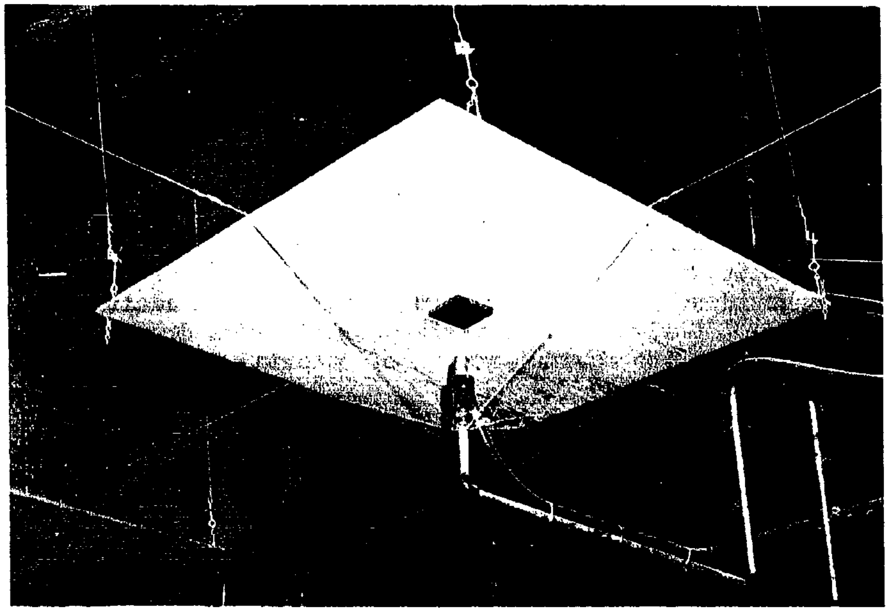


Fig. 8 Individual Fallout Disperser

of the particles were fed to the nozzle where an air stream picked it up and blasted it against the deflector plate. The particles scattered and fell over the 8 x 8-ft area covered by each individual disperser. A detailed description of this dispersal system is given elsewhere.[14]

3. EXPERIMENTAL PROCEDURES

Preliminary tests were conducted on all test surfaces except tar and gravel with 30, 45, and 60-min fallout periods, to determine if the length of the dispersal period had a significant influence on the effectiveness of the washdown.

A fallout period of 30-min at a rate of 2 gram/min/ft^2 was used in all the effectiveness studies because it is a high rate that exceeds what normally might be encountered in fallout from multimegaton land surface nuclear detonation.

In all fallout removal tests, fallout dispersal was started after the washdown water was turned on and the test surfaces were completely wetted. The washdown water was allowed to flow for an additional 30-min after cessation of fallout. This washdown period was determined to be sufficient to remove the maximum amount of material that could be removed by the washdown system.

The particles removed from the surfaces during this 1-hr washdown period were collected in 200 mesh sieves (Fig. 9). After the washdown water was turned off, the sieves were replaced, and the residual fallout simulant on the surfaces was removed by a 30-min flushing manually with a garden hose. Longer and repeated flushing removed more material but the additional percent removed was very small after the first 15-min flushing period (see Table I). A 30-min post-washdown flushing with a garden hose was selected as standard procedure instead of a 15-min flush for added assurance of effective removal.

The simulated fallout particles removed during the washdown period and the residual particles later removed with the garden hose were weighed wet by submerging the sieves and simulated fallout particles in water, allowing them to drain for exactly 10-min, and then weighing them on a platform scale. This technique eliminated the time delay in drying the samples. The wet weight of the particles was determined in calibration tests to be 1.27 times the dry weight for the 177-350 μ simulant and the 1.29 for the 297-590 μ simulant.

The test conditions used for the various surfaces are summarized in Table II. One test run was made at each set of test conditions on all test surfaces.

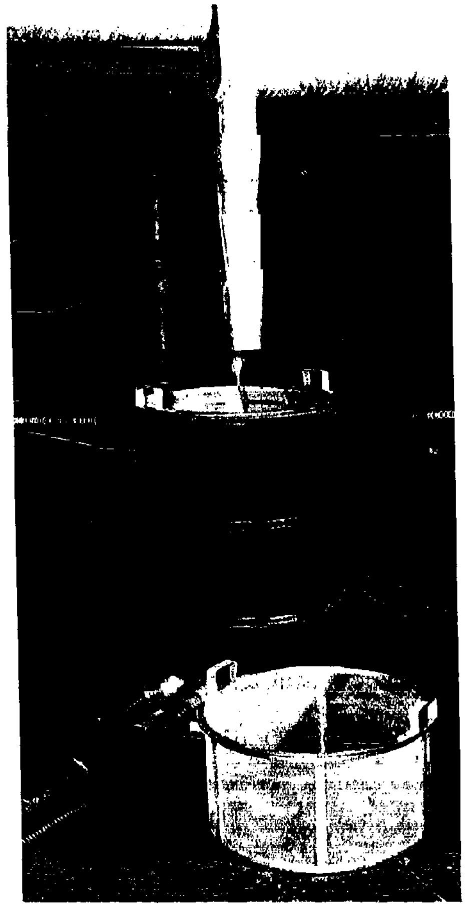


Fig. 9 Sieves Used to Collect Particles Removed From Roof

TABLE I

Effect of Post-Washdown Flushing Time on Flushing Effectiveness
(Slope, 1:8; Particle Size, 177 to 350 μ)

Test Surface	Water Flow (gpm/ft)	Removed During Washdown (grams)	Residual as Determined by Flushing With a Garden Hose for Different Flushing Periods					
			15 min		30 min		45 min	
			g	%	g	%	g	%
Masonite	3.0	27,058	85	0.3	113	0.4	113	0.4
Aluminum Shingles	3.0	26,354	1418	5.0	1460	5.2	1602	5.7
Composition Shingles	3.5	23,461	2721	10.4	2823	10.7	3189	12.0

TABLE II

Test Conditions
(Roof Length - 48 ft)

(Particle Size 177-350 μ and 350-590 μ)

Roof Surface	Slope	Water Flow Rate (gal/min/ft of width)
Fiberglass Epoxy Laminate	1:24, 1:12, 1:8, 1:6, 1:4	0.3 to 5.0
Tempered Pressed Board (Masonite)	1:24, 1:12, 1:8, 1:6, 1:4	0.5 to 4.2
Roll Roofing	1:24, 1:12, 1:8, 1:6, 1:4	0.5 to 6.0
Aluminum Shingles	1:24, 1:12, 1:8, 1:6, 1:4	1.0 to 6.0
Composition Shingles	1:24, 1:12, 1:8, 1:6, 1:4	1.0 to 4.5
Tar and Gravel	1:24 and 1:12	3.0 to 8.0

The test procedure for the tar and gravel surface was modified to include a 60-min pre-washing to remove the loose gravel. The first test on this surface was made at a slope of 1:12 with a water flow rate of 8.0 gal/min/ft of width.

At the conclusion of the test series outlined in Table II, a limited number of tests were conducted on 12-, 24- and 36-ft lengths of all surfaces except tar and gravel to determine the effect of roof length on washdown effectiveness. This was done by covering the plane with 4-ft wide aluminum sheets, as shown in Fig. 10, and shutting off certain of the dispersers. In all cases the nozzles remained at the top of the surface and the washdown water flowed down the test surface under the cover panels before it came to the exposed test area, where simulated fallout material was being deposited.

4. RESULTS AND DISCUSSION

The 30-min fallout period was selected on the basis of the results given in Table III. These results show greater residual mass for longer fallout periods, but very small variations in the percent residual figures. These small variations are probably within the reproducibility of the experiment, however it appears necessary to conduct additional studies to determine the effect of heavy mass loadings over longer fallout periods.

The washdown effectiveness results, for five surfaces (excluding tar and gravel) at the various slopes with different water flow rates, are shown in Figs. 11 to 15 for the 177-350 μ particles and Figs. 16 to 20 for the 297-590 μ particles plotted as percent residual vs water flow rate. The tabulated results are given in Appendix B. Of these 5 surfaces, composition shingles (Figs. 15 and 20) showed the highest percentage of residual mass. A slope of 1:8 or higher and a water flow rate of at least 4 gal/min/ft of width are required on this surface to reduce the residual mass to less than 10 %. These same conditions on the composition roll roofing (Figs. 13 and 18) and the aluminum shingles (Figs. 14 and 19) reduced the residual to 5 % or less. A flow rate of only 2-1/2 to 3 gal/min/ft of width is required on the aluminum shingle surface at a slope of 1:8 to give at most 10 % residual mass and 2 to 2-1/2 gal/min/ft of width on the roll roofing. The laminated plastic surface at a slope of 1:8 was washed clean of all but 1/2 % or less of the

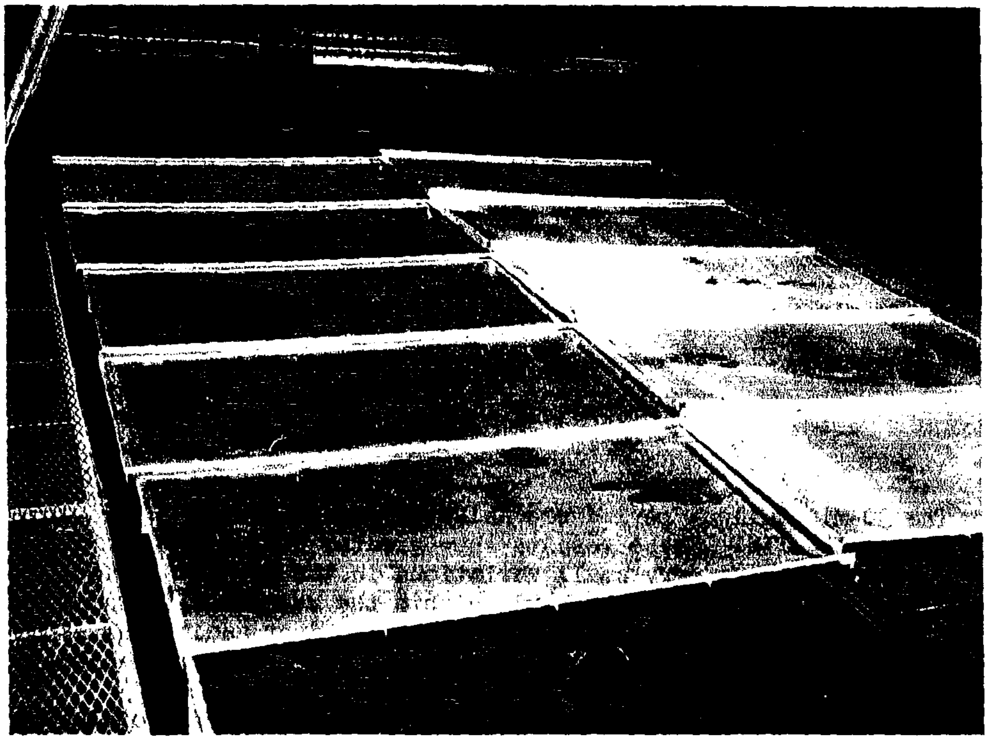


Fig. 10 Reduction of Test Surface Length With Cover Plates

TABLE III

Washdown Effectiveness for Various Fallout Dispersal Periods
(Deposition Rate, 2 g/min/sq ft; Particle Size, 177-350 μ)

Test Surface	Slope	Water Flow (gal/min/ft of width)	Residual for Different Dispersal Periods					
			30 min Dispersal (grams)	30 min Dispersal %	45 min Dispersal (grams)	45 min Dispersal %	60 min Dispersal (grams)	60 min Dispersal %
Masonite	1:8	0.5	290	1.2	290	1.2		
Alum. Shingles	1:8	5.1	536	2.2	614	2.6		
Comp. Shingles	1:8	1.25	2570	11.9	2882	13.1		
Masonite	1:8	0.5	358	1.7	380	1.8		
Alum. Shingles	1:8	5.0	525	2.4	592	2.7		
Comp. Shingles	1:8	1.25	2458	12.9	2737	14.1		
Masonite	1:8	0.5	313	1.3	380	1.5		
Alum. Shingles	1:8	5.0	525	2.1	581	2.3		
Comp. Shingles	1:8	1.25	2625	11.8	2905	12.9		
Fiberglass Laminate	1:8	2.0	45	0.2			67	0.14
Fiberglass Laminate	1:6	2.0	11	0.1			89	0.2
Fiberglass Laminate	1:4	1.8	11	0.1			67	0.14
Roll Roofing	1:8	4.0	1586	5.6			1743	3.3
Roll Roofing	1:6	4.0	860	3.7			1598	3.0
Roll Roofing	1:4	2.6	871	3.6			1039	2.1

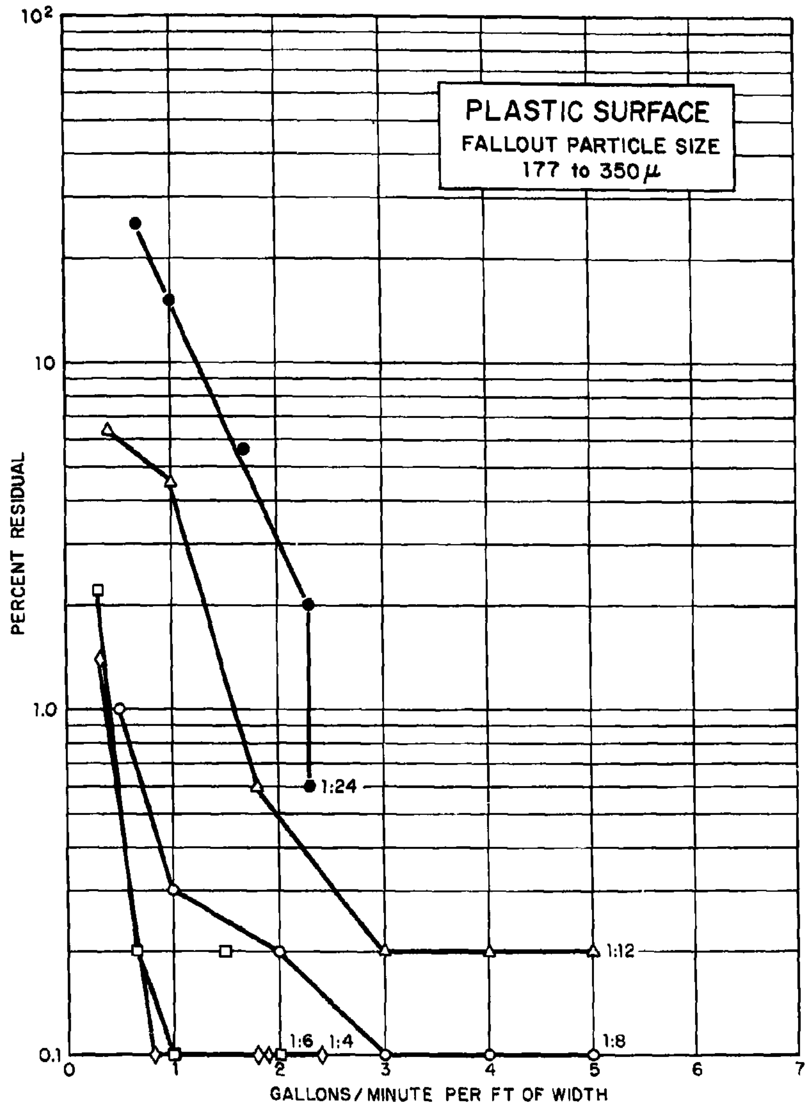


Fig. 11 Effectiveness of Removing 177-350 μ Particles on Plastic Surface

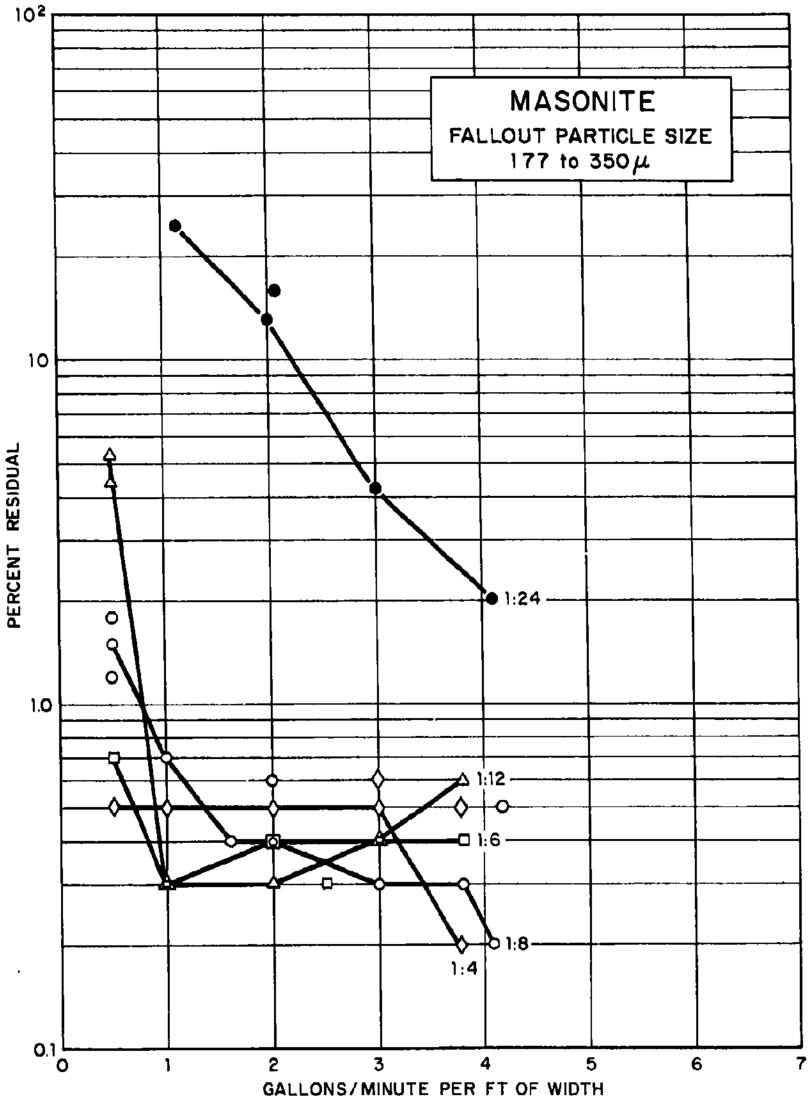


Fig. 12 Effectiveness of Removing 177-350 μ Particles on Masonite Surfaces

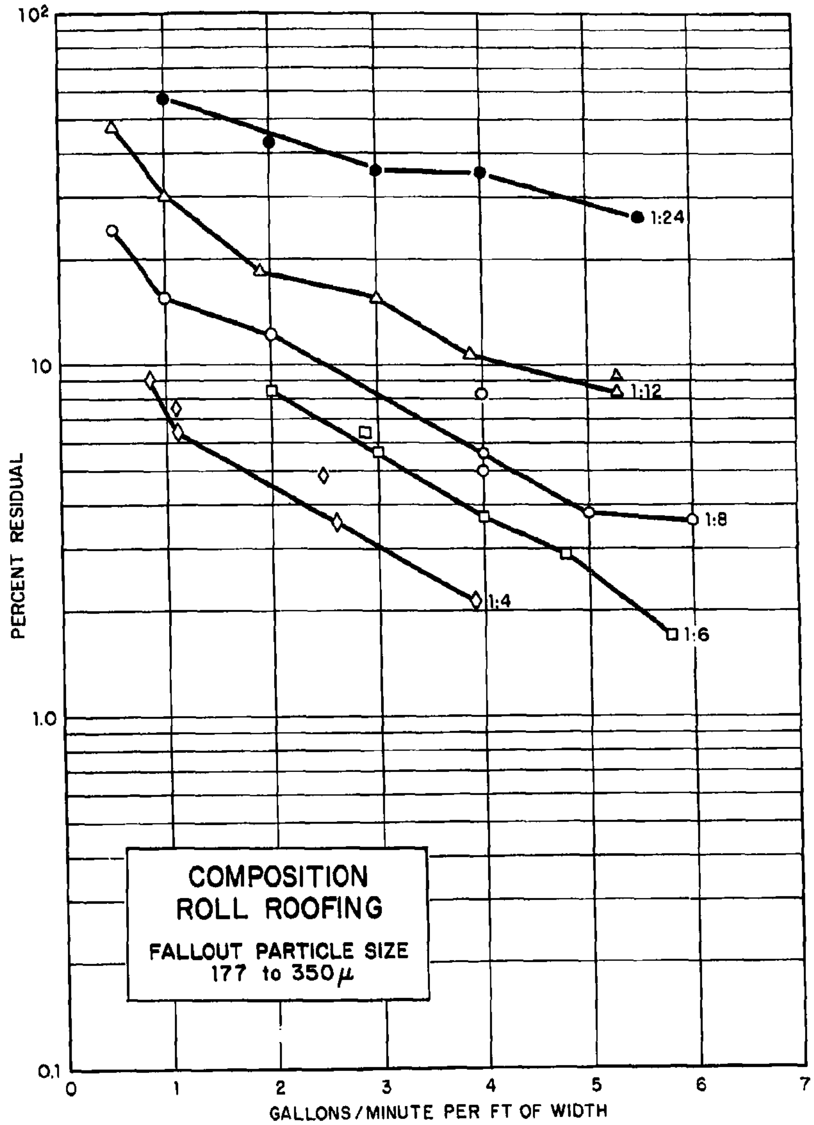


Fig. 13 Effectiveness of Removing 177-350 μ Particles on Roll Roofing Surfaces

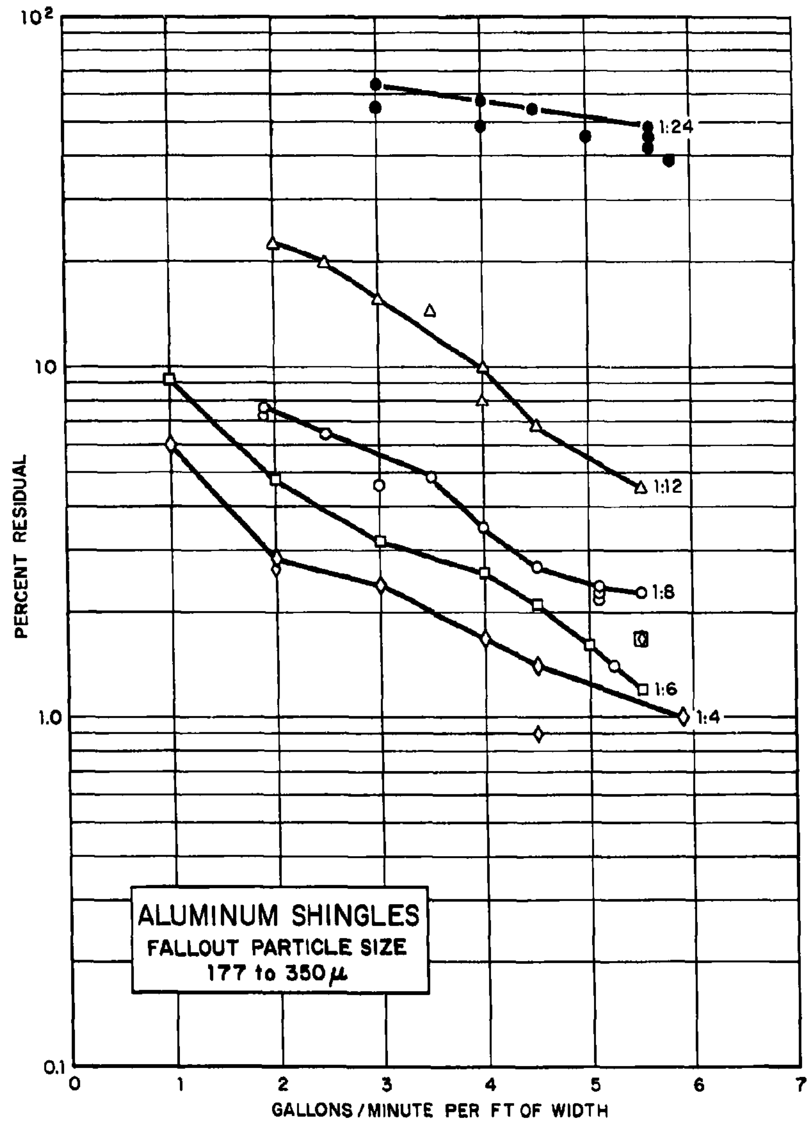


Fig. 14 Effectiveness of Removing 177-350 μ Particles on Aluminum Shingle Surfaces

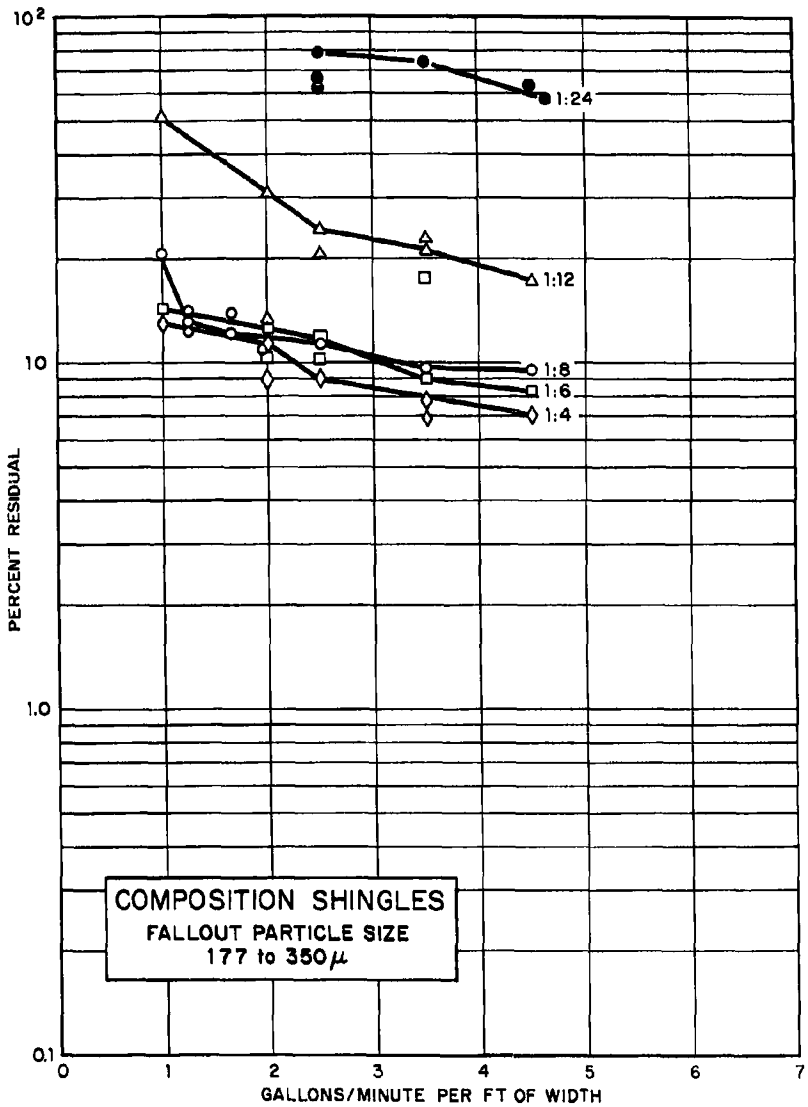


Fig. 15 Effectiveness of Removing 177-350 μ Particles on Composition Shingle Surface

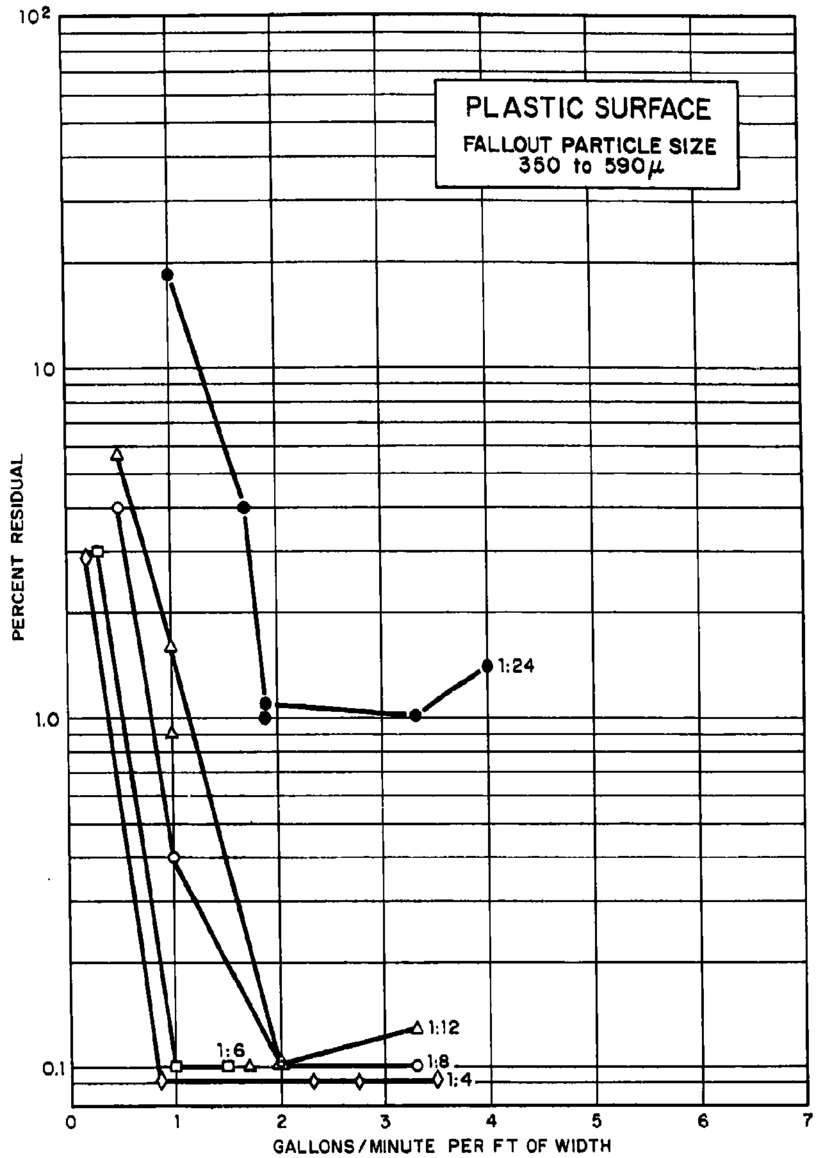


Fig. 16 Effectiveness of Removal of 350-590 μ Particles on Plastic Surfaces

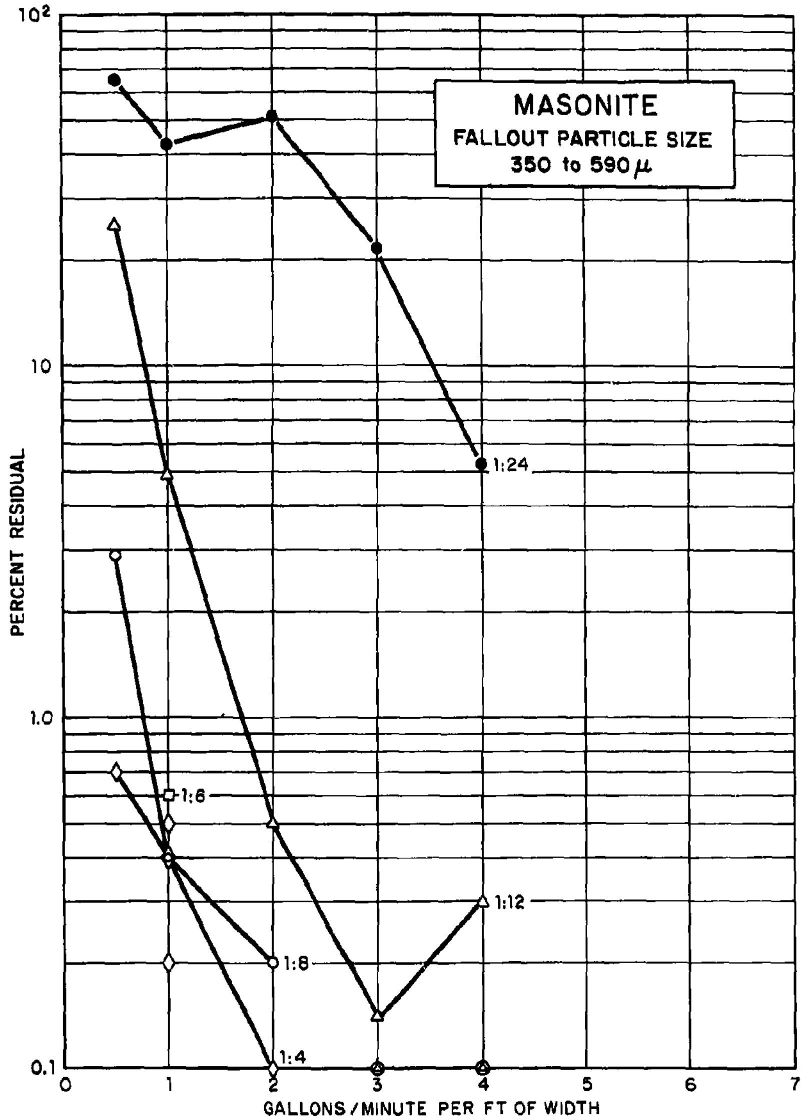


Fig. 17 Effectiveness of Removal of 350-590 μ Particles on Masonite Surfaces

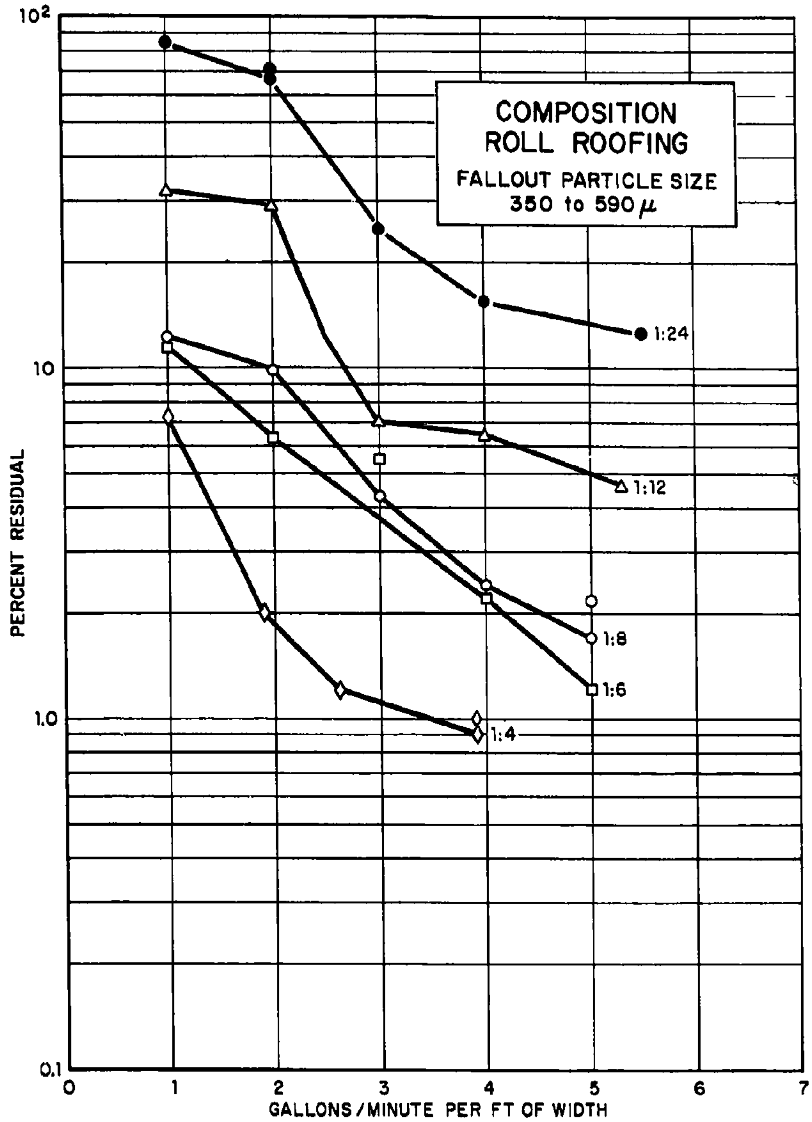


Fig. 18 Effectiveness of Removal of 350-590 μ Particles on Roll Roofing Surfaces

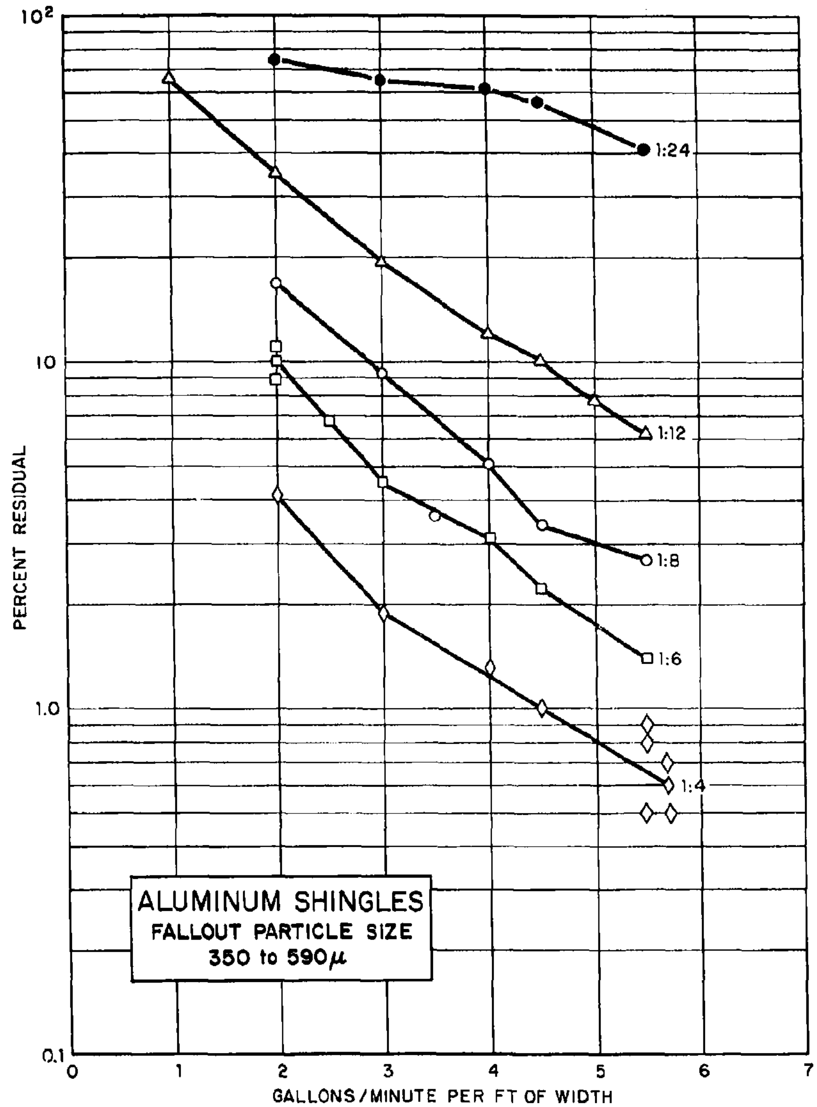


Fig. 19 Effectiveness of Removal of 350-490 μ Particles on Aluminum Shingle Surface

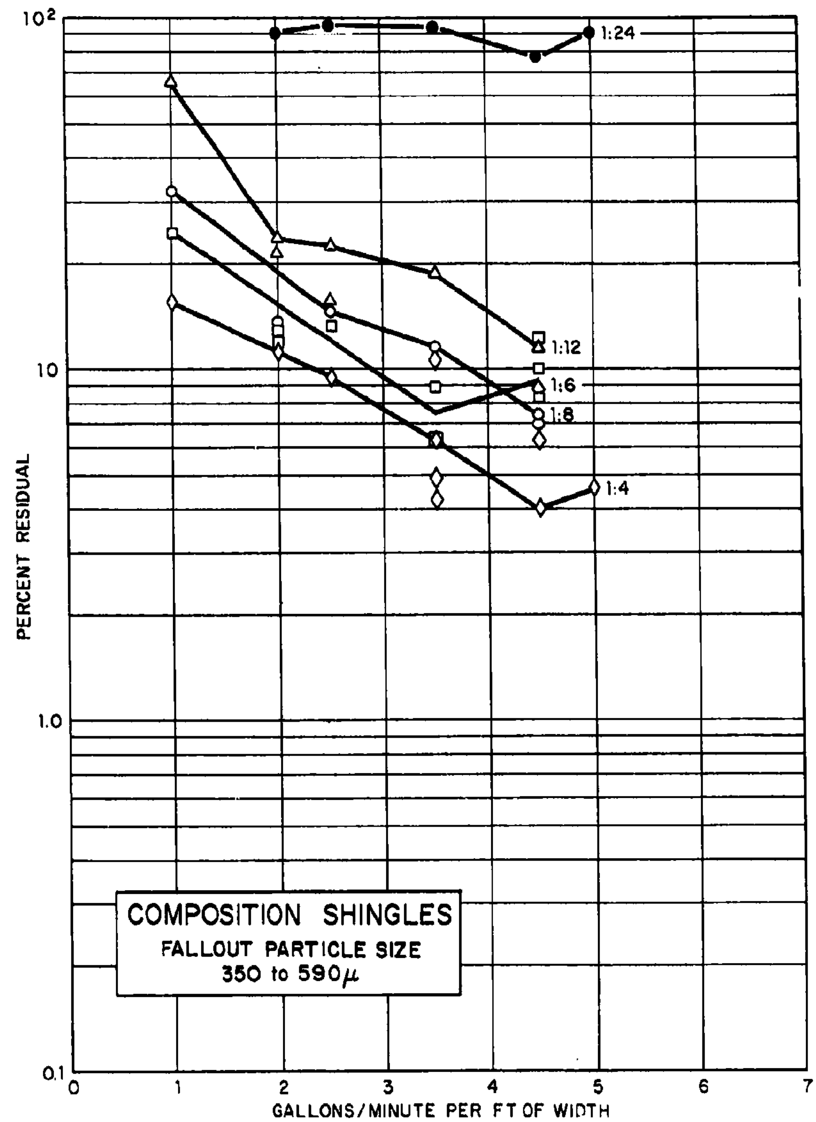


Fig. 20 Effectiveness of Removal of 350-490 μ Particles on Composition Shingle Surface

particles with a water flow rate of only 1 gal/min/ft of width. The required flow rate for all of these surfaces might be somewhat higher under field conditions due to surface irregularities.

No significant difference can be seen between the results obtained with the two particle size ranges tested. Therefore data will be required on additional particle size ranges before the effect of particle size can be determined.

The reproducibility of the results is shown in Fig. 19 where six tests were made on the aluminum shingle surface at a slope of 1:4 with a water flow rate of approximately 5.5 gal/min/ft of width. The average percent residual was 0.66, with a standard deviation of $\pm$ 0.16.

The tar and gravel surface at a slope of 1:12 was flushed with the washdown water for 60-min before the dispersal of fallout material was started on the first run. The water formed several channels through the gravel (Fig. 21), and about 75 lb of gravel was removed. This was approximately 8-1/2 % of the 875 lb of gravel originally on the test surface. An additional 25 lb of gravel was washed off during the first run (No. 235), making a total of 11-1/2 % of the original gravel removed. The surface retained 45 % of the fallout during this test with a water flow of 8.0 gal/min/ft of width (Table IV). A water flow of only 4 gal/min/ft of width gave a residual of 61 %.

Prior to the start of run 238, all the loose gravel was removed with a water hose, rubber squeegee, and shovel. A total of 573 lb of gravel was removed, leaving approximately 35 % of the original gravel embedded in the tar (Fig. 22). A flow of 8.0 gal/min/ft of width removed 86 % of the fallout from the surface in this condition, but 3 gal/min/ft of width removed only 47 % of the fallout.

With the slope of the plane reduced to 1:24, 8 gal/min/ft of width removed only 49 % of the fallout, and 3 gal/min/ft of width removed only approximately 35 %.

In general the larger particle size range, 350-590 μ, gave 50 % higher residual on the tar and gravel surface under the same test conditions.

The effect of roof length on percent residual for several surfaces is given in Table V. The results with the different plane lengths are identical except for minor variations.

Fig. 21 Tar and Gravel Surface After First 60-min Prewash

TABLE IV

Washdown Effectiveness on Tar and Gravel Roofing

Run No.	Slope	Water Flow gpm/ft	Condition of Loose Gravel	Fallout Deposited Grams	Gravel Removed During Washdown	Fallout Residual Grams	Fallout Residual %
			Fallout Particle Size - 177-350 μ				
235	1:12	8.0	Original amount[1]	22775	100 lbs[2]	10240	45.0
236	1:12	4.0	Not replaced after run 235	24373	2 lbs	14910	61.2
237	1:12	3.0	Not replaced after 236	23553	1 oz	15543	66.0
238	1:12	8.0	Removed with high pressure hose and shovel (573 lbs)	25080	-	3474	13.9
239	1:12	8.0	Not replaced after run 238	27829	-	4994	17.9
241	1:12	5.5	Not replaced after run 238	29594	-	7608	25.7
240	1:12	3.0	Not replaced after run 238	21014	-	11194	53.3
242	1:24	8.0	Not replaced after run 238	30399	-	15540	51.1
243	1:24	5.5	Not replaced after run 238	30912	-	18654	60.3
244	1:24	3.0	Not replaced after run 238	28634	-	18389	64.2
			Fallout Particle Size - 350-590 μ				
314	1:12	8.0	All gravel replaced	22860	62-1/2 lbs	13838	60.5
316	1:12	4.0	All gravel replaced	20897	1 oz	20711	99.4
315	1:12	4.0	Removed with high pressure hose & shovel	22461	-	9884	44.0
311	1:24	8.0	Gravel replaced	17439	Not measured	17177	98.5
313	1:24	4.0	Gravel replaced	16263	2 oz	16034	98.6
312	1:24	4.0	Removed with high pressure hose & shovel	17465	-	17083	97.8
317	1:24	4.0	Removed with high pressure hose & shovel	18936	-	18214	96.2

1. A total of 870 lbs of gravel, or approximately 2.3 lb/ft^2, was used.
2. 75 lbs of this 100 lbs removed during a 60 min prewash.

Fig. 22 Tar and Gravel Surface After Run 238, With the Loose Gravel Removed Showing Accumulated Fallout Simulant

TABLE V

Effect of Plane Length on Washdown Effectiveness

Surface	Slope	Water Flow gpm/ft	Plane Length: 12 ft Grams Residual	12 ft % Residual	24 ft Grams Residual	24 ft % Residual	36 ft Grams Residual	36 ft % Residual	48 ft Grams Residual	48 ft % Residual
Roll Roofing	1:8	4.0	302	4.0	513	4.3	682	3.7	1966	5.6
Roll Roofing	1:8	4.0	302	5.2	592	5.8	716	4.5	1207	5.0
Roll Roofing	1:6	3.3	201	3.4	492	4.4	581	3.1		
Roll Roofing	1:4	2.6	190	3.0	402	3.1	592	3.2	871	3.6
Comp. Shingles	1:6	1.0			1352	13.8			2927	14.4
Comp. Shingles	1:6	2.5			905	11.7			2190	10.3
Comp. Shingles	1:6	4.5			927	10.2			1821	8.3
Alum. Shingles	1:6	2.0			570	5.4			1084	4.8
Alum. Shingles	1:6	4.0			246	2.9			536	2.6
Alum. Shingles	1:6	5.5			246	2.6			469	1.2
Masonite	1:6	1.5			34	0.3			67	0.3
Masonite	1:6	2.0			6	0.1			78	0.4
Masonite	1:6	3.8			34	0.4			89	0.4
Plastic	1:12	1.8	34	0.6	34	0.3	56	0.3	134	0.6
Plastic	1:8	2.0	11	0.2	22	0.2	22	0.2		0.2

5. INTERPRETATION OF RESULTS

The results presented in Figs. 11 to 20 show that the amount of fallout removed by the washdown countermeasure on a roofing surface can be varied over wide limits by changing the slope of the surface or the water flow rate, or both. However the effectiveness of a washdown system is limited to a great extent by the type of roofing surface. For example, with fiberglass epoxy laminate it is possible to remove all but 1/10 of 1 % of the fallout, but on surfaces like composition shingles it is prohibitively difficult to remove more than 92 to 93 % of the fallout.

Figures 23 through 27 show the slope and minimum water flow rates on the various surfaces that will provide 90, 95, and 99 % removal of the simulated fallout.

Figures 23 and 24 show the water flow required to give 90 % removal for the different surfaces at various slopes for the 177-350 μ and 350-590 μ particles respectively. The tar and gravel surface is not included because 90 % removal cannot be accomplished with washdown under the test conditions. Figures 25 and 26 show the water flow required to give 95 % removal for different slopes. The composition shingle surface is not included because it retained 7 % or more fallout at all conditions tested. If a removal of 99 % is required, the only surfaces which can be used are the near-ideal surfaces. Figure 27 shows the water flow requirements to remove 99 % of both sizes of fallout particles from the plastic surface at various slopes.

6. CONCLUSIONS

A slope of at least 1:8 and a water flow rate of at least 4 gal/min/ft of width is required on the composition shingles to reduce the residual contamination to less than 10 %. A flow rate of only 2-1/2 to 3 gal/min/ft of width is required on an aluminum shingle roof at a slope of 1:8 to give at least 90 % removal, and 2-2-1/2 gal/min/ft of width is required on roll roofing. A fiberglass epoxy laminated roof at a slope of at least 1:8 will have more than 99 % of the fallout removed with a water flow of only 1 gal/min/ft of width.

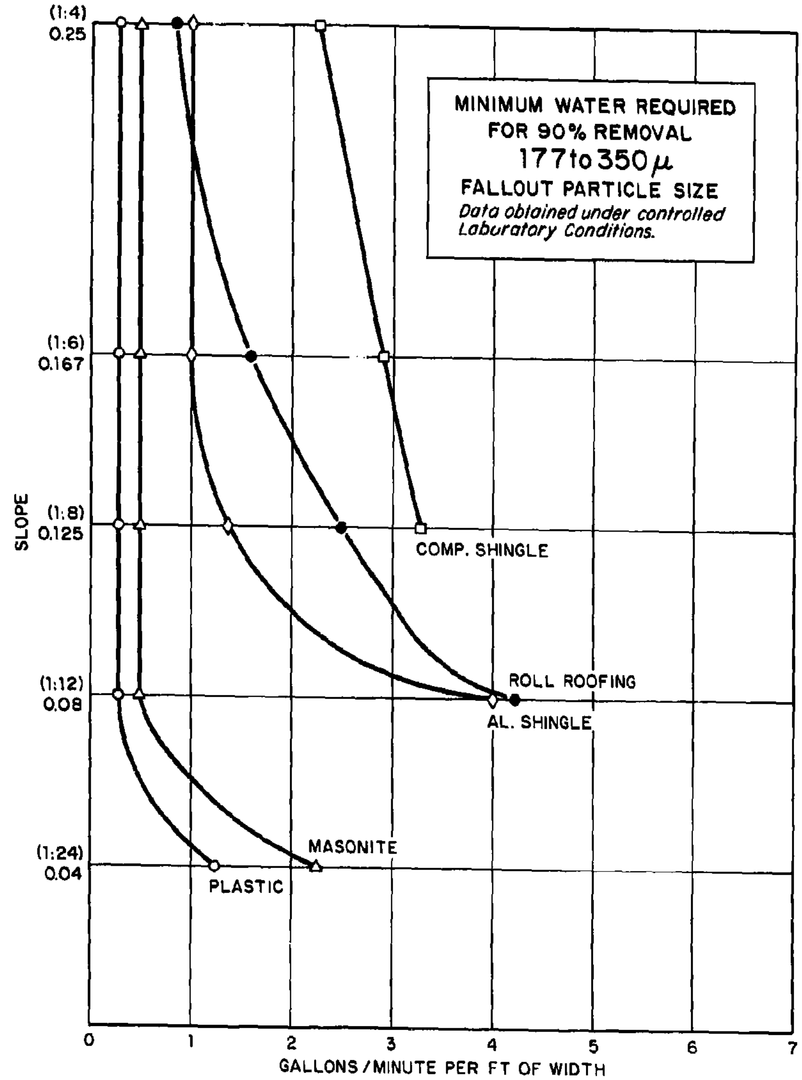


Fig. 23 Minimum Water Required for 90 % Removal of 177-350 μ Particles

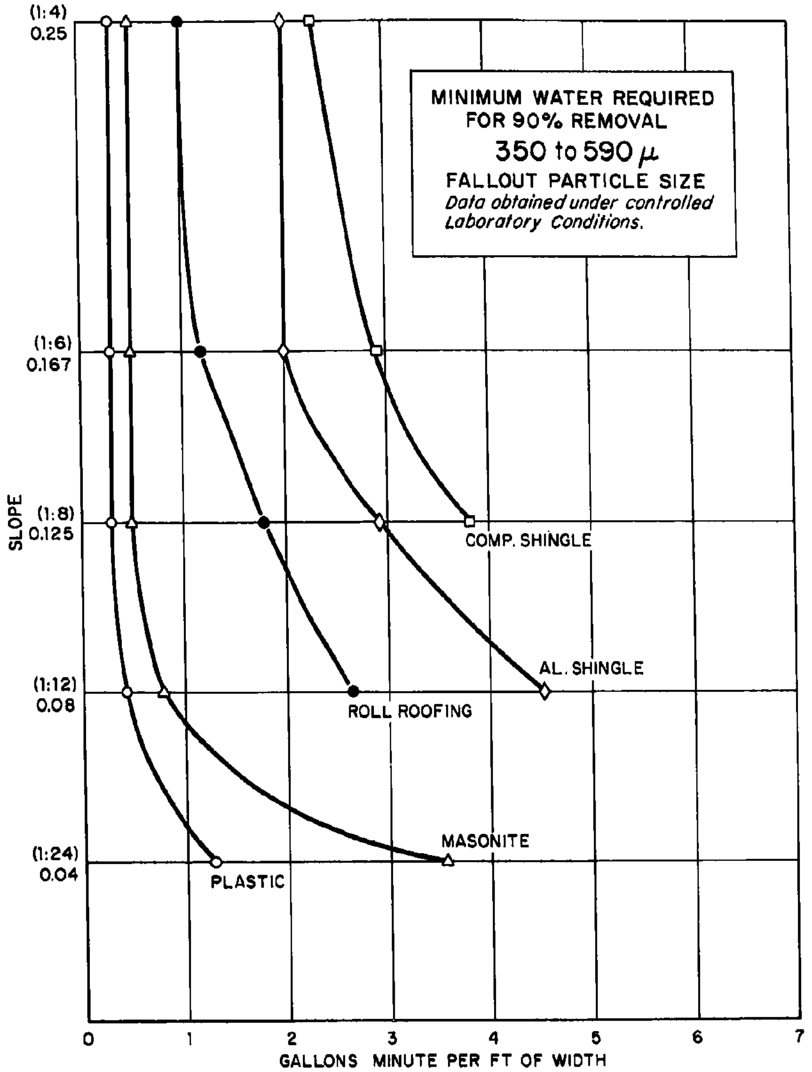


Fig. 24 Minimum Water Required for 90 % Removal of 350-590 μ Particles

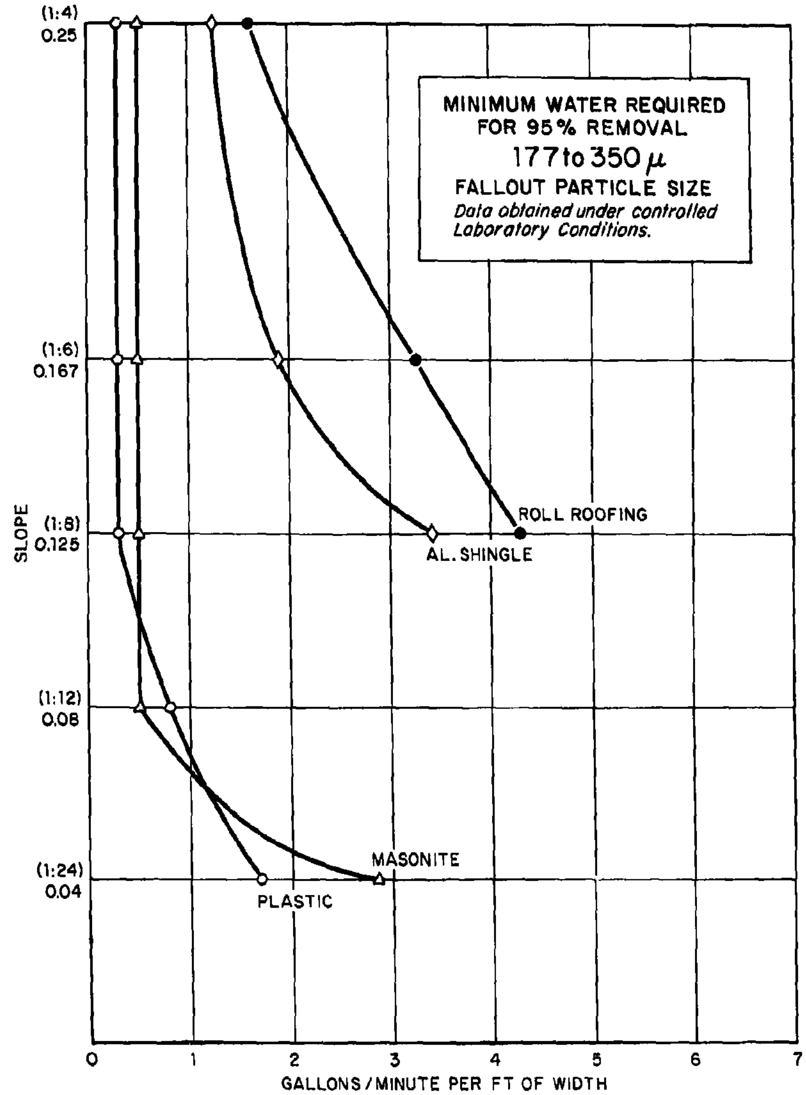


Fig. 25 Minimum Water Required for 95 % Removal of 177-350 μ Particles

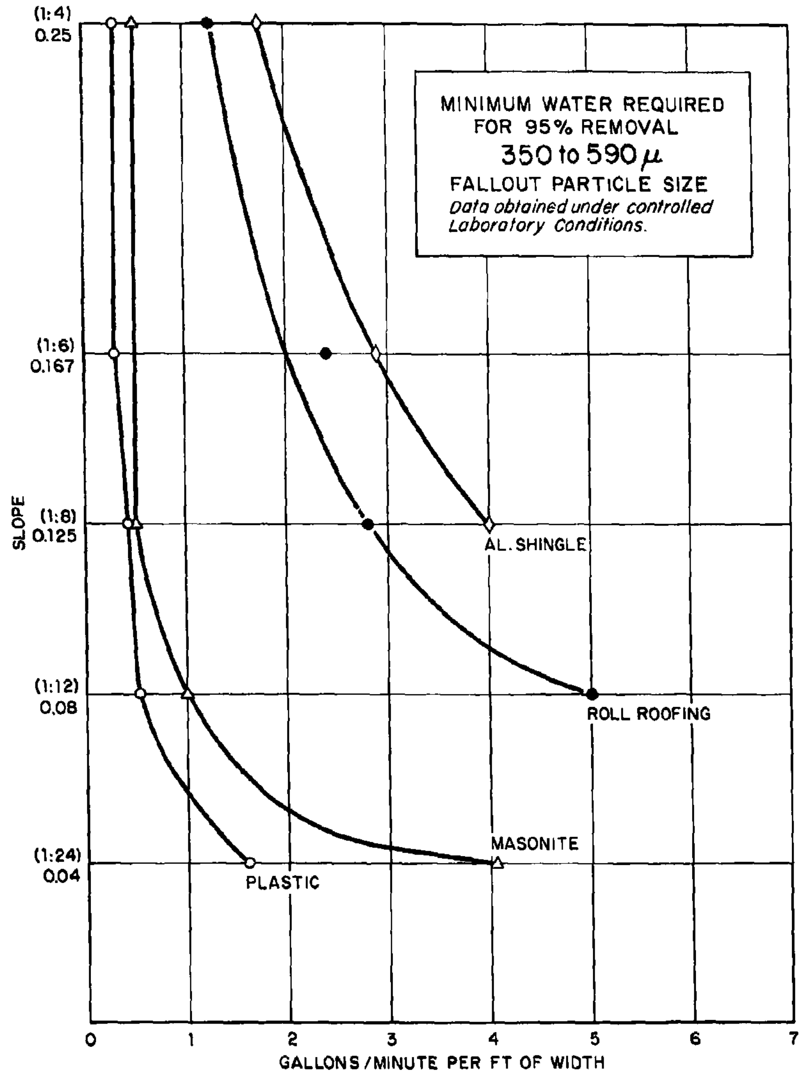


Fig. 26 Minimum Water Required for 95 % Removal of 350-590 μ Particles

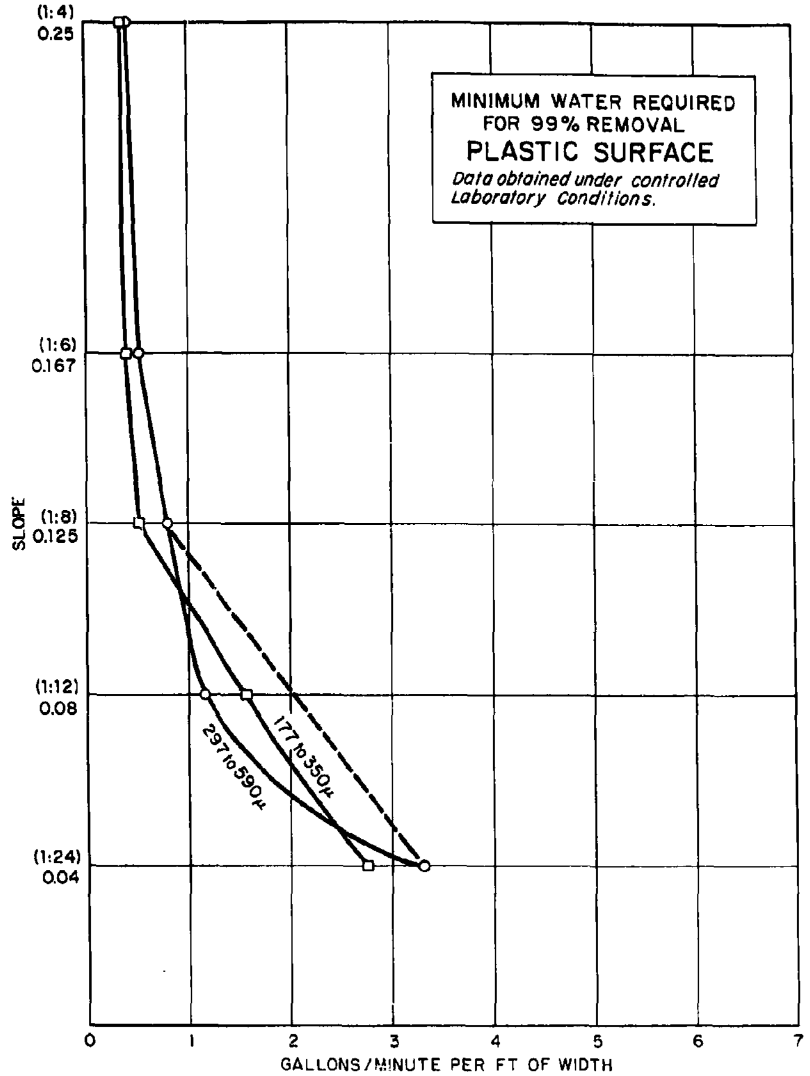


Fig. 27 Minimum Water Required for 99 % Removal of 177-350 μ and 350-590 μ Particles From Plastic Surface

Washdown is ineffective on a tar and gravel roof if the loose gravel is not removed prior to turning on the washdown. After the loose gravel is removed, up to 85 % of the simulant particles can be removed with a flow rate of 8 gal/min/ft of roof width at a slope of 1:12.

No significant difference can be seen in the results obtained with the two particle size ranges tested.

7. RECOMMENDATIONS

It is recommended that: (1) tests be continued with the other particle sizes to determine if there is an effect of particle size on the washdown effectiveness; (2) tests be conducted to study the effect of fallout rate and total mass on washdown effectiveness.

REFERENCES

1. R. R. Soule, R. L. Stetson, W. G. Neall. Efficacy of a Contact Water Curtain in Preventing or Minimizing Contamination. U. S. Naval Radiological Defense Laboratory Report, USNRDL-AD-187(T), 3 January 1950 (Classified).

2. M. M. Bigger, Field Evaluation of Washdown Effectiveness. U. S. Naval Radiological Defense Laboratory Report, USNRDL-361, 1 May 1952 (Classified).

3. M. M. Bigger, H. R. Rinnert, J. C. Sherwin, F. K. Kawahara, H. Lee. Field Effectiveness Tests of a Washdown System on an Aircraft Carrier. U. S. Naval Radiological Defense Laboratory Report, USNRDL-416, 3 June 1953 (Classified).

4. G. G. Molumphy, M. M. Bigger. Proof Testing of AW Ship Countermeasures, Operation CASTLE, Project 6.4. AFSWP, WT-927, 25 October 1957 (Classified).

5. M. B. Hawkins, et al. Determination of Radiological Hazards to Personnel, Operation WIGWAM, Project 2.4. AFSWP, WT-1012, July 1956 (Official Use Only).

6. M. M. Bigger, H. B. Curtis, W. J. Armstrong. Verification of the Effectiveness of Shipboard Washdown Countermeasures, Operation REDWING, Project 2.10. AFSWP, Preliminary Report, ITR-1324, July 1957 (Classified).

7. W. L. Owen. Interim Design and Evaluation of a Contact Water Curtain, Against Fallout, for Roofing Materials. U. S. Naval Radiological Defense Laboratory Technical Report, USNRDL-TR-123, 29 November 1957.

8. R. H. Heiskell, R. J. Crew, A. J. Guay. Transport of Particulate Matter on a Near Horizontal Ideal Surface. U. S. Naval Radiological Defense Laboratory Technical Report, USNRDL-TR-360, 25 September 1959.

9. R. H. Heiskell, R. J. Crew, R. H. Black, S. Salkin, A. J. Guay. Transport of Particulate Matter on an Ideal Surface at 0.02 Slope. U. S. Naval Radiological Defense Laboratory Technical Report, USNRDL-TR-404, March 1960.

10. R. H. Heiskell, R. J. Crew, S. Salkin, P. A. Loeb, L. Herrington, A. J. Guay. Transport of Particulate Matter on an Ideal Surface at 0.04 Slope. U. S. Naval Radiological Defense Laboratory Technical Report, USNRDL-TR-416, 29 March 1960.

11. R. H. Heiskell, R. J. Crew, P. A. Loeb. Transport of Particulate Matter on an Ideal Surface at 0.08 Slope. U. S. Naval Radiological Defense Laboratory Technical Report, USNRDL-TR-436, 7 July 1960.

12. R. H. Heiskell, R. J. Crew, S. Salkin. Transport of Particulate Matter on an Ideal Surface at 0.165 Slope. U. S. Naval Radiological Defense Laboratory Technical Report, USNRDL-TR-437, 7 July 1960.

13. W. S. Kehrer, M. B Hawkins. Feasibility and Applicability of Roof Washdown System. U. S. Naval Radiological Defense Laboratory Technical Report, USNRDL-TR-232, 7 May 1958.

14. W. S. Kehrer. A Disperser for Depositing Simulated Dry Fallout Material on Large Roof Surfaces. U. S. Naval Radiological Defense Laboratory Technical Report, USNRDL-TR-609, 13 December 1962.

APPENDIX A

Sieve Analysis of Simulated Fallout

A. 177 to 350 μ particles

Sieve Size U.S. Bu. Stds No.	Opening in Microns	% Retained on Sieve[1]				
		Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Ave. of 4 Samples
45	350	2.1	1.1	2.1	2.5	2.0
50	300	13.5	8.9	13.0	14.7	12.5
80	177	79.5	84.2	81.0	79.8	81.1
100	149	3.1	3.8	2.5	1.9	2.8
200	74	1.7	2.0	1.0	0.6	1.3
Pan	-	Trace	Trace	Trace	Trace	Trace
Total		99.9	100.0	99.6	99.5	99.7

B. 350 to 590 μ particles

Sieve Size U.S. Bu. Stds No.	Opening in Microns	% Retained on Sieve[1]					
		Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5	Ave. of 5 Samples
25	710	0.4	0.1	0.1	0.1	0.1	0.2
30	590	1.6	1.2	0.9	0.9	0.9	1.1
35	500	16.1	15.4	11.9	13.1	12.3	13.8
40	420	39.0	40.4	38.0	40.2	39.4	39.4
45	350	38.5	38.0	41.9	37.3	41.1	39.4
Pan	-	3.9	3.9	6.8	7.3	6.2	5.6
Total		99.5	99.0	99.6	98.9	99.6	99.5

1. Sample taken at random from supply hopper during tests.

APPENDIX B

WASHDOWN EFFECTIVENESS ON 5 ROOFING SURFACES

TABLE B.1

Surface - Tempered pressed board
Particle size - 177 to 350 μ
Surface dimensions - 8 ft wide by 48 ft long
Fallout deposition - 2 grams/min/sq ft for 30 min
Washdown period - During fallout plus 30 min after fallout period

Run No.	Water Flow gal/min/ft width	Fallout Deposited[1] Total Grams Deposited	Fallout Deposited[1] grams/min/sq ft	Residual[2] Grams	Residual[2] Percent
			Slope 1 to 24		
161	1.15	13,261	1.15	3184	24.0
225	2.0	22,679	1.97	2938	13.0
162	2.1	24,478	2.12	3899	15.9
163	3.0	24,020	2.08	1017	4.2
164	4.1	22,355	1.94	447	2.0
		Ave.	1.85		
			Slope 1 to 12		
160	0.5	20,076	1.74	927	4.6
141	0.5	22,019	1.91	1195	5.4
140	1.0	19,685	1.71	67	0.3
139	2.0	22,165	1.92	56	0.3
138	3.0	20,969	1.82	89	0.4
228	3.0	25,002	2.17	89	0.4
137	3.8	22,946	1.99	134	0.6
227	3.8	19,986	1.73	78	0.4
		Ave.	1.87		
			Slope 1 to 8		
111	0.5	23,148	2.01	291	1.2
112	0.5	21,070	1.83	380	1.8
113	0.5	24,645	2.09	380	1.5
114	1.0	21,729	1.89	145	0.7
115	1.6	25,718	2.23	112	0.4
116	2.0	23,260	2.02	134	0.6
230	2.0	23,215	2.02	89	0.4
117	3.0	27,147	2.36	89	0.3
118	3.8	26,745	2.32	89	0.3
229	4.1	23,294	2.02	34	0.2
119	4.2	26,321	2.28	134	0.5
		Ave.	2.10		
			Slope 1 to 6		
128	0.5	22,198	1.93	145	0.7
129	1.0	23,461	2.04	67	0.3
130	2.0	20,746	1.80	78	0.4
232	2.5	21,908	1.90	56	0.3
131	3.0	22,634	1.96	89	0.4
231	3.0	22,623	1.96	89	0.4
132	3.8	23,572	2.05	89	0.4
		Ave.	1.95		
			Slope 1 to 4		
125	0.5	22,220	1.93	101	0.5
124	1.0	16,981	1.47	89	0.5
123	2.0	20,534	1.78	112	0.5
122	3.0	23,561	2.05	134	0.6
126	3.0	19,997	1.74	89	0.5
233	3.0	27,572	2.39	22	0.1
121	3.8	21,607	1.88	112	0.5
234	3.8	25,036	2.17	56	0.2
		Ave.	1.93		

1. Fallout deposited or determined by actual weighing.
2. Residual Fallout was determined by weighing the residual removed after completion of run.

TABLE B.2

Surface - Aluminum shingle
Particle size - 177 to 350 μ
Surface dimensions - 7.5 ft width by 48 ft length
Fallout period - 30 min
Washdown period - During fallout plus 30 min after fallout period

Run No.	Water Flow gal/min/ft width	Fallout Deposited		Residual	
		Total Grams Deposited	Grams/min/sq ft	Grams	Percent
			Slope 1 to 24		
146	3.0	19,037	1.76	12,155	63.8
163	3.0	24,600	2.28	13,417	54.5
145	4.0	16,422	1.52	9,373	57.1
162	4.0	23,226	2.15	11,384	49.0
144	4.5	19,584	1.81	10,781	55.0
225	5.0	22,534	2.09	10,345	45.9
142	5.65	19,729	1.83	8,781	44.5
143	5.65	17,696	1.64	8,702	49.2
161	5.65	13,362	1.24	5,776	43.2
164	5.8	23,103	2.14	8,993	38.9
		Ave.	1.85		
			Slope 1 to 12		
141	2.0	21,662	2.01	4,904	22.6
228	2.5	25,349	2.35	5,061	20.0
140	3.0	19,696	1.82	3,005	15.3
227	3.5	20,813	1.93	2,994	14.4
139	4.0	22,624	2.09	1,788	7.9
160	4.0	22,288	2.06	2,156	9.7
138	4.5	20,869	1.93	1,408	6.7
137	5.5	23,852	2.21	1,073	4.5
		Ave.	2.05		
			Slope 1 to 8		
118	1.95	26,947	2.50	1,955	7.3
119	1.95	26,243	2.43	1,989	7.6
230	2.5	23,539	2.18	1,508	6.4
117	3.0	27,616	2.56	1,262	4.6
229	3.5	23,763	2.20	1,162	4.9
116	4.0	24,265	2.25	838	3.5
115	4.5	26,299	2.44	704	2.7
111	5.1	23,896	2.21	536	2.2
112	5.1	21,605	2.00	525	2.4
113	5.1	24,813	2.30	581	2.3
120	5.25	52,944	2.45	760	1.4
114	5.5	22,400	2.07	525	2.3
		Ave.	2.30		
			Slope 1 to 6		
231	1.0	21,953	2.03	2,022	9.2
128	2.0	22,455	2.08	1,084	4.8
129	3.0	23,830	2.21	771	3.2
130	4.0	20,947	1.94	536	2.6
131	4.5	22,455	2.08	480	2.1
232	5.0	22,433	2.08	369	1.6
132	5.5	23,908	2.21	402	1.7
136	5.5	40,297	1.87	469	1.2
		Ave.	2.06		
			Slope 1 to 4		
126	1.0	20,075	1.86	1,195	6.0
234	2.0	24,757	2.29	620	2.7
125	2.0	22,757	2.11	637	2.8
124	3.0	17,619	1.63	425	2.4
123	4.0	21,104	1.95	358	1.7
122	4.5	24,064	2.23	346	1.4
127	4.5	51,190	2.37	436	0.9
121	5.5	22,388	2.07	391	1.7
233	5.9	28,019	2.59	279	1.0
		Ave.	2.12		

TABLE B.3

Surface - Composition shingle
Particle size - 177 to 350 μ
Surface dimensions - 7.5 ft wide by 48 ft long
Fallout period - 30 min
Washdown period - During fallout plus 30 min after fallout

Run No.	Water Flow gal/min/ft width	Fallout Deposited		Residual	
		Total Grams Deposited	Grams/min/sq ft	Grams	Percent
		Slope 1 to 24			
145	2.5	15,317	1.33	10,836	70.7
163	2.5	22,176	1.92	13,697	61.8
225	2.5	19,115	1.66	12,490	65.3
144	3.5	17,529	1.52	12,334	70.4
142	4.5	17,462	1.52	11,038	63.2
143	4.5	14,378	1.25	9,250	64.3
146	4.5	18,959	1.65	12,490	65.9
161	4.5	13,462	1.17	8,524	63.3
164	4.65	22,143	1.92	12,837	58.0
		Ave.	1.55		
		Slope 1 to 12			
141	1.0	20,344	1.77	10,580	52.0
140	2.0	18,109	1.57	5,552	30.7
139	2.5	20,199	1.75	4,190	20.7
227	2.5	16,221	1.41	3,977	24.5
159	2.5	15,607	1.35	3,731	23.9
160	2.5	20,461	1.78	5,117	25.0
138	3.5	17,696	1.54	3,821	21.6
228	3.5	23,316	2.02	5,497	23.6
137	4.5	20,903	1.81	3,609	17.3
		Ave.	1.67		
		Slope 1 to 8			
230	1.0	20,969	1.80	4,312	20.6
111	1.25	21,919	1.90	2,882	13.1
112	1.25	19,350	1.68	2,737	14.1
113	1.25	22,601	1.96	2,905	12.9
114	1.66	19,752	1.71	2,804	14.2
119	1.66	24,690	2.14	2,983	12.1
115	1.95	24,310	2.11	2,670	11.0
116	2.5	22,422	1.95	2,547	11.4
117	3.5	25,975	2.25	2,514	9.7
118	4.5	25,840	2.24	2,491	9.6
		Ave.	1.97		
		Slope 1 to 6			
128	1.0	20,266	1.76	2,927	14.4
232	2.0	20,423	1.77	2,190	10.7
129	2.0	22,746	1.97	2,838	12.4
231	2.5	21,227	1.84	2,190	10.3
130	2.5	20,120	1.75	2,368	11.8
131	3.5	21,461	1.86	1,933	9.0
229	3.5	20,411	1.77	3,631	17.8
132	4.5	21,930	1.90	1,821	8.3
		Ave.	1.83		
		Slope 1 to 4			
125	1.0	21,025	1.82	2,726	13.0
234	2.0	22,980	1.99	2,033	8.8
126	2.0	19,517	1.69	2,234	11.5
125	2.0	16,534	1.43	2,156	13.0
123	2.5	19,238	1.67	1,732	9.0
122	3.5	22,523	1.95	1,553	6.9
233	3.5	25,606	2.22	1,989	7.8
121	4.5	21,763	1.89	1,553	7.1
		Ave.	1.83		

TABLE B.4

Surface - Plastic
Particle size - 177 to 350 μ
Surface dimensions - 8 ft wide by 48 ft long
Fallout period - 30 minutes
Washdown period - During fallout plus 30 min after fallout

Run No.	Water Flow gal/min/ft width	Fallout Deposited		Residual	
		Total Grams Deposited	Grams/min/sq ft	Grams	Percent
		Slope 1 to 24			
165	0.7	24,299	2.11	6,066	25.0
166	1.0	25,595	2.22	3,832	15.0
167	1.7	25,896	2.25	1,452	5.6
168	2.3	23,651	2.05	469	2.0
169	2.3	23,287	2.11	156	0.6
		Ave.	2.14		
		Slope 1 to 12			
176	0.42	21,853	1.90	1,397	6.4
175	1.0	21,528	1.87	994	4.6
174	1.8	21,126	1.83	134	0.6
173	3.0	19,797	1.72	45	0.2
177	4.0	22,232	1.93	45	0.2
171	5.0	21,138	1.83	45	0.2
		Ave.	1.80		
		Slope 1 to 8			
182	0.5	28,689	2.49	290	1.0
181	1.0	21,799	1.89	56	0.3
185	1.0	23,640	2.05	67	0.3
180	2.0	21,272	1.85	34	0.2
184	2.0	22,153	1.92	44	0.2
216	2.0	27,215	2.36	45	0.2
212	3.0	23,093	2.00	22	0.1
179	4.0	24,478	2.12	34	0.1
178	5.0	25,539	2.22	34	0.1
		Ave.	2.10		
		Slope 1 to 6			
186	0.3	24,232	2.10	525	2.2
187	1.0	24,500	2.13	11	0.1
188	0.63	22,668	1.97	34	0.2
203	1.5	24,221	2.10	45	0.2
189	2.0	24,544	2.13	11	0.1
		Ave.	2.09		
		Slope 1 to 4			
192	0.36	21,607	1.86	313	1.4
193	0.83	23,148	2.01	22	0.1
194	0.94	23,495	2.04	34	0.1
195	1.8	22,422	1.95	11	0.1
200	1.9	23,484	2.04	45	0.2
196	2.4	22,522	1.95	22	0.1
		Ave.	1.97		

TABLE B.5

Surface - Rolled roofing
Particle size - 177 to 350 μ
Surface dimensions - 8 ft wide by 48 ft long
Fallout period - 30 minutes
Washdown period - During fallout plus 30 min after fallout

Run No.	Water Flow gal/min/ft width	Fallout Deposited		Residual	
		Total Grams Deposited	Grams/min/sq ft	Grams	Percent
		Slope 1 to 24			
165	1.0	26,667	2.31	15,406	57.8
166	2.0	28,063	2.44	12,110	43.2
167	3.0	27,471	2.38	9,697	35.3
168	4.0	25,818	2.24	9,139	35.4
169	5.5	26,645	2.31	7,038	26.4
		Ave.	2.33		
		Slope 1 to 12			
176	0.5	22,713	1.97	10,580	46.6
177	1.0	22,567	1.96	6,882	30.5
175	1.0	22,254	1.93	6,904	31.0
174	1.9	22,053	1.91	4,055	18.4
173	3.0	21,942	1.90	3,441	15.7
172	3.9	23,226	2.02	2,469	10.6
171	5.3	23,048	2.00	2,201	9.5
170	5.3	23,617	2.05	2,011	8.5
		Ave.	1.97		
		Slope 1 to 8			
178	0.5	28,511	2.47	6,927	24.3
179	1.0	26,432	2.29	4,055	15.3
180	2.0	24,176	2.10	2,916	12.1
181	4.0	23,695	2.06	1,966	8.3
184	4.0	24,321	2.11	1,207	5.0
216	4.0	28,298	2.46	1,586	5.6
185	5.0	25,640	2.23	972	3.8
182	6.0	31,996	2.78	1,184	3.7
		Ave.	2.31		
		Slope 1 to 6			
190	2.0	27,226	2.36	2,290	8.4
189	2.9	24,712	2.15	1,609	6.5
203	3.0	26,254	2.28	1,475	5.6
188	4.0	23,137	2.01	860	3.7
187	4.8	26,132	2.27	749	2.9
186	5.8	24,019	2.09	402	1.7
		Ave.	2.19		
		Slope 1 to 4			
196	0.84	23,272	2.02	2,112	9.1
195	1.1	22,868	1.98	1,742	7.6
200	1.1	24,131	2.09	1,553	6.4
194	2.5	25,382	2.20	1,251	4.9
193	2.6	24,332	2.11	871	3.6
192	3.9	22,500	1.95	469	2.
		Ave.	2.06		

TABLE B.6

Surface - Tempered pressed board
Particle size - 350 to 495 μ
Surface dimensions - 8 ft wide by 48 ft long
Fallout period - 30 minutes
Washdown period - During fallout plus 30 min after fallout

Run No.	Water Flow gal/min/ft width	Fallout Deposited: Total Grams Deposited	Fallout Deposited: Grams/min/sq ft	Residual: Grams	Residual: Percent
		Slope 1 to 24			
278	0.5	13,213	1.15	8,604	65.1
279	1.0	15,499	1.35	6,688	43.2
280	2.0	18,696	1.62	9,709	51.0
281	3.0	18,422	1.60	4,006	21.7
282	4.0	17,032	1.48	909	5.3
		Ave.	1.44		
		Slope 1 to 12			
277	0.5	15,182	1.32	3,853	25.4
276	1.0	16,342	1.42	799	4.9
271	2.0	15,806	1.37	77	0.5
272	3.0	13,912	1.21	11	0.1
275	3.0	15,249	1.32	22	0.14
273	4.0	16,649	1.45	44	0.3
274	4.0	15,249	1.32	11	0.1
		Ave.	1.34		
		Slope 1 to 8			
265	0.5	11,854	1.03	339	2.9
266	1.0	15,937	1.38	66	0.4
267	2.0	14,691	1.28	33	0.2
268	3.0	15,072	1.31	11	0.07
269	4.0	13,580	1.18	6	0.04
		Ave.	1.25		
		Slope 1 to 6			
264	1.0	11,516	1.00	66	0.6
		Ave.	1.00		
		Slope 1 to 4			
249	0.5	18,367	1.59	131	0.7
248	1.0	19,035	1.65	33	0.2
250	1.0	17,295	1.50	66	0.4
252	1.0	17,507	1.52	88	0.5
253	1.0	14,669	1.27	66	0.5
247	2.0	20,162	1.75	22	0.1
246	3.0	23,731	2.06	22	0.09
245	3.8	31,533	2.74	11	0.03
		Ave.	1.76		

TABLE B.7

Surface - Aluminum shingle
Particle size - 350 to 495 μ
Surface dimensions - 8 ft wide by 48 ft long
Fallout period - 30 minutes
Washdown period - During fallout plus 30 min after fallout

Run No.	Water Flow gal/min/ft width	Fallout Deposited		Residual	
		Total Grams Deposited	Grams/min/sq ft	Grams	Percent
		Slope 1 to 24			
282	2.0	17,831	1.65	13,518	75.8
281	3.0	20,147	1.87	13,234	65.7
280	4.0	21,947	2.03	13,365	60.9
279	4.5	19,516	1.81	11,066	56.7
278	5.5	16,410	1.52	6,667	40.6
		Ave.	1.78		
		Slope 1 to 12			
276	1.0	17,438	1.61	11,680	67.0
275	2.0	17,220	1.59	6,042	35.1
274	3.0	16,824	1.56	3,339	19.8
273	4.0	19,198	1.78	2,331	12.1
272	4.5	16,254	1.51	1,675	10.3
277	5.0	17,119	1.59	1,357	7.9
271	5.5	18,487	1.71	1,171	6.3
		Ave.	1.62		
		Slope 1 to 8			
269	2.0	15,358	1.42	2,594	16.9
268	3.0	17,208	1.59	1,598	9.3
270	3.5	17,051	1.58	646	3.8
267	4.0	16,627	1.54	909	5.5
266	4.5	18,400	1.70	624	3.4
265	5.5	16,988	1.57	460	2.7
		Ave.	1.57		
		Slope 1 to 6			
260	2.0	17,821	1.65	2,003	11.2
261	2.0	19,757	1.83	1,970	10.0
262	2.0	18,772	1.74	1,675	8.9
264	2.0	17,394	1.61	1,762	10.1
263	2.5	19,573	1.81	1,336	6.8
259	3.0	19,473	1.80	876	4.5
258	4.0	19,374	1.79	602	3.1
257	4.5	18,881	1.75	405	2.2
256	5.5	23,370	2.16	318	1.4
		Ave.	1.79		
		Slope 1 to 4			
249	2.0	22,504	2.08	1,051	4.7
248	3.0	23,347	2.16	449	1.9
247	4.0	25,076	2.32	317	1.3
246	4.5	29,323	2.72	295	1.0
245	5.5	34,042	3.15	263	0.8
250	5.5	21,563	1.98	197	0.9
252	5.5	20,743	1.92	99	0.5
253	5.7	17,983	1.67	120	0.7
254	5.7	21,234	1.97	120	0.6
255	5.75	18,269	1.69	99	0.5
		Ave.	2.17		

TABLE B.8

Surface - Composition shingle
Particle size - 350 to 495 μ
Surface dimensions - 8 ft wide by 48 ft long
Fallout period - 30 minutes
Washdown period - During fallout plus 30 min after fallout

Run No.	Water Flow gal/min/ft width	Fallout Deposited: Total Grams Deposited	Fallout Deposited: Grams-min/sq ft	Residual: Grams	Residual: Percent
		Slope 1 to 24			
278	2.0	11,538	1.00	10,498	91.0
279	2.5	14,930	1.30	14,197	95.1
280	3.5	17,021	1.48	16,058	94.3
281	4.5	16,879	1.47	14,810	77.4
282	5.0	15,401	1.34	14,033	91.1
		Ave.	1.32		
		Slope 1 to 12			
275	1.0	14,492	1.26	9,588	66.2
274	2.0	13,661	1.19	2,977	21.8
277	2.0	14,592	1.27	3,426	23.5
273	2.5	15,468	1.34	2,463	15.9
276	2.5	15,172	1.32	3,470	22.9
272	3.5	13,114	1.14	2,474	18.9
271	4.5	13,519	1.17	1,565	11.6
		Ave.	1.24		
		Slope 1 to 8			
269	1.0	12,479	1.08	4,280	34.3
268	2.0	13,805	1.20	1,894	13.7
267	2.5	13,191	1.14	1,937	14.7
266	3.5	14,471	1.26	1,686	11.7
265	4.5	15,455	1.34	1,116	7.2
270	4.5	13,412	1.16	996	7.4
		Ave.	1.20		
		Slope 1 to 6			
260	1.0	13,761	1.19	3,404	24.7
259	2.0	15,041	1.31	1,948	13.0
261	2.0	15,554	1.35	1,883	12.1
258	2.5	15,050	1.31	1,981	13.2
257	3.5	13,979	1.21	865	6.2
264	3.5	15,915	1.38	1,412	8.9
256	4.5	17,458	1.52	1,412	8.1
262	4.5	15,380	1.33	1,861	12.1
263	4.5	15,160	1.32	1,522	10.0
		Ave.	1.32		
		Slope 1 to 4			
249	1.0	16,353	1.42	2,605	15.9
248	2.0	17,579	1.53	2,036	11.6
247	2.5	18,859	1.64	1,828	9.7
246	3.5	22,832	1.98	2,386	10.5
250	3.5	16,167	1.40	1,018	6.3
252	3.5	14,656	1.27	624	4.3
253	3.5	13,310	1.16	657	4.9
245	4.5	29,214	2.54	1,850	6.3
251	4.5	10,978	0.95	974	8.9
254	4.5	16,189	1.41	446	4.0
255	5.0	14,404	1.25	657	4.6
		Ave.	1.50		

TABLE B.9

Surface - Plastic
Particle size - 350 to 495 µ
Surface dimensions - 8 ft wide by 48 ft long
Fallout period - 30 minutes
Washdown period - During fallout plus 30 min after fallout

Run No.	Water Flow gal/min/ft width	Fallout Deposited		Residual	
		Total Grams Deposited	Grams/min/sq ft	Grams	Percent
		Slope 1 to 24			
287	1.0	17,044	1.48	3,229	18.9
288	1.7	13,846	1.20	558	4.0
285	1.9	18,794	1.63	197	1.1
286	1.9	17,252	1.50	164	1.0
284	3.3	19,199	1.67	186	1.0
283	4.0	18,039	1.57	252	1.4
		Ave.	1.51		
		Slope 1 to 12			
294	0.5	18,486	1.60	1,062	5.7
290	1.0	16,780	1.46	263	1.6
291	1.0	15,521	1.35	142	0.9
289	1.7	14,974	1.30	11	0.07
292	2.0	16,841	1.46	6	0.03
293	3.3	17,294	1.50	22	0.13
		Ave.	1.44		
		Slope 1 to 8			
295	0.5	17,044	1.48	657	4.0
296	1.0	13,990	1.21	55	0.4
297	2.0	18,137	1.57	11	0.06
298	3.3	17,229	1.50	11	0.06
299	3.3	17,574	1.53	6	0.03
300	3.3	17,733	1.54	0	0
		Ave.	1.47		
		Slope 1 to 6			
305	0.3	19,757	1.71	591	3.0
304	1.0	18,072	1.57	11	0.06
303	1.4	18,575	1.61	11	0.06
302	3.3	17,646	1.53	11	0.06
301	3.8	17,092	1.48	6	0.03
		Ave.	1.58		
		Slope 1 to 4			
306	0.2	17,995	1.56	515	2.9
307	0.8	17,382	1.51	11	0.06
308	2.3	19,319	1.68	11	0.06
309	2.7	17,700	1.54	11	0.06
310	3.5	15,860	1.38	0	0
		Ave.	1.53		

TABLE B.10

Surface - Rolled roofing
Particle size - 350 to 495 μ
Surface dimensions - 8 ft wide by 48 ft long
Fallout period - 30 minutes
Washdown period - During fallout plus 30 min after fallout

Run No.	Water Flow gal/min/ft width	Fallout Deposited: Total Grams Deposited	Fallout Deposited: Grams/min/sq ft	Residual: Grams	Residual: Percent
		Slope 1 to 24			
288	1.0	14,635	1.27	12,533	85.6
287	2.0	21,686	1.88	15,238	70.3
286	2.0	20,886	1.81	14,165	67.8
285	3.0	24,453	2.12	6,097	24.9
284	4.0	24,836	2.16	3,831	15.4
283	5.5	24,070	2.09	3,065	12.7
		Ave.	1.89		
		Slope 1 to 12			
289	1.0	19,440	1.69	6,283	32.3
290	2.0	21,531	1.87	6,316	29.3
294	2.5	20,405	1.77	2,474	12.1
291	3.0	20,031	1.74	1,401	7.0
292	4.0	22,089	1.92	1,445	6.5
293	5.3	20,044	1.74	930	4.6
		Ave.	1.79		
		Slope 1 to 8			
295	1.0	21,751	1.89	2,638	12.1
296	2.0	17,811	1.55	1,763	9.9
297	3.0	23,676	2.06	1,007	4.3
298	4.0	22,504	1.95	547	2.4
299	5.0	22,898	1.99	493	2.2
300	5.0	23,206	2.01	504	1.7
		Ave.	1.91		
		Slope 1 to 6			
305	1.0	25,755	2.24	3,010	11.7
304	2.0	23,873	2.07	1,511	6.3
303	3.0	23,983	2.08	1,314	5.5
302	4.0	22,822	1.98	504	2.2
301	5.0	22,395	1.94	263	1.2
		Ave.	2.06		
		Slope 1 to 4			
306	1.0	23,435	2.03	1,664	7.10
307	1.9	23,217	2.02	515	2.0
308	3.9	24,277	2.11	219	0.9
309	2.6	23,775	2.06	285	1.2
310	3.9	21,366	1.85	208	1.0
		Ave.	2.01		

INITIAL DISTRIBUTION

Copies	
	NAVY
3	Chief, Bureau of Ships (Code 210L)
2	Chief, Bureau of Ships (Code 320)
1	Chief, Bureau of Medicine and Surgery
1	Chief, Bureau of Naval Weapons (Code RRRE-5)
1	Chief, Bureau of Yards and Docks (Code 42.330)
1	Chief, Bureau of Yards and Docks (Code 50)
1	Chief, Bureau of Supplies and Accounts (Code L12)
1	Chief of Naval Operations (OP-07T10)
1	Chief of Naval Research (Code 104)
1	CO-Dir. U.S. Naval Civil Engineering Lab.
1	U.S. Naval Civil Engineering Corps Officers School
1	Chief of Naval Personnel (Code Pers M12)
	ARMY
1	Assistant Secretary of the Army (R&D)
1	Coordinator, Marine Corps Landing Force Dev. Activities
1	Army Materiel Command, Nuclear Branch (AMCRD-DE-N)
1	Chief of Engineers (ENGTE)
1	Chief of Engineers (ENGMC-DO)
1	Dir. Waterways Experiment Station
1	Army Chemical Corps
3	Army Library, Civil Defense Unit
1	Aberdeen Proving Ground (Ballistics Lab.)
	AIR FORCE
1	Directorate of Civil Engineering (AFOCE-ES)
1	Air Force Weapons Laboratory
1	Dir. USAF Project RAND
	OTHER DOD ACTIVITIES
2	Chief, Atomic Support Agency (Library)
60	Office of Civil Defense (Dir. for Research)
20	Defense Documentation Center
2	Defense Atomic Support Agency, Sandia Base, Albuquerque

2	Office of Emergency Planning (Technical Analysis Div.)
1	OSD, I&L
1	Public Works Planning Branch (DCS/LOG)
1	Engineer Res. & Dev. Laboratory
1	Chief, Joint Civil Defense Support Group
1	AFCIN 3K2
1	Standards & Criteria Branch (AFOCE-ES)

AEC ACTIVITIES AND OTHERS

1	Ammann & Whitney
2	Armour Research Foundation
1	Atomic Energy Commission Div. of Biology and Medicine
2	Atomic Energy Commission (Dr. Dunham)
1	Broadview Research Corporation
1	Cornell Aeronautical Laboratory
1	Eberle M. Smith Assoc. Inc.
1	General American Transportation Co.
1	Hayes, Seay, Mattern & Mattern
1	Mariana and Associates
1	Massachussetts Institute of Technology
1	National Academy of Sciences
2	National Bureau of Standards
1	Office of Civil Defense (Acorn Park)
1	Office of Civil Defense (Guy B. Panero)
1	Sandia Corporation (Underground Physics Div.)
1	Stanford Research Institute
2	Technical Operations Inc.
1	University of Arizona
2	University of Illinois
1	University of Massachussetts
1	Vare Industries, Inc.
1	Research Triangle Institute
25	Div. of Technical Services, Oak Ridge

USNRDL

50	Technical Information Division

DISTRIBUTION DATE: 2 December 1963

Naval Radiological Defense Laboratory
USNRDL-TR-672
DESIGN CRITERIA FOR ROOF WASHDOWN SYSTEM Phase 1. Fallout Removal Studies on Typical Roofing Surfaces for Two Size Ranges of Particles (177-350 μ and 350-590 μ) by R.H. Heiskell, W.S. Kehrer, N.J. Vella and G. Brown 18 July 1963 75 p. tables illus. 14 refs.
UNCLASSIFIED

Fallout simulant particles ranging in size from 177 to 350 and 350 to 590 microns were deposited on selected typical roof sections 48 ft
(over)

1. Washdown.
2. Roofs.
3. Surface properties.
4. Particles.
5. Fallout.
I. Heiskell, R.H.
II. Kehrer, W.S.
III. Vella, N.J.
IV. Brown, G.
V. Title.

UNCLASSIFIED

Naval Radiological Defense Laboratory
USNRDL-TR-672
DESIGN CRITERIA FOR ROOF WASHDOWN SYSTEM Phase 1. Fallout Removal Studies on Typical Roofing Surfaces for Two Size Ranges of Particles (177-350 μ and 350-590 μ) by R.H. Heiskell, W.S. Kehrer, N.J. Vella and G. Brown 18 July 1963 75 p. tables illus. 14 refs.
UNCLASSIFIED

Fallout simulant particles ranging in size from 177 to 350 and 350 to 590 microns were deposited on selected typical roof sections 48 ft
(over)

1. Washdown.
2. Roofs.
3. Surface properties.
4. Particles.
5. Fallout.
I. Heiskell, R.H.
II. Kehrer, W.S.
III. Vella, N.J.
IV. Brown, G.
V. Title.

UNCLASSIFIED

long by 8 ft wide to determine the effect of water flow rate, slope, and surface type on washdown effectiveness. More than 90% of the simulant can be removed on composition shingles, aluminum shingles and roll roofing at slopes of 1:12 or steeper with 2 to 3 gallons of water per min per ft of roof width (gpm/ft). It was found that washdown is ineffective on tar and gravel roofing without prior removal of the loose gravel. Washdown on a fiberglass epoxy laminated roof will remove better than 99% of the simulant particles with a water flow rate as low as 1 gal/min/ft.

UNCLASSIFIED

long by 8 ft wide to determine the effect of water flow rate, slope, and surface type on washdown effectiveness. More than 90% of the simulant can be removed on composition shingles, aluminum shingles and roll roofing at slopes of 1:12 or steeper with 2 to 3 gallons of water per min per ft of roof width (gpm/ft). It was found that washdown is ineffective on tar and gravel roofing without prior removal of the loose gravel. Washdown on a fiberglass epoxy laminated roof will remove better than 99% of the simulant particles with a water flow rate as low as 1 gal/min/ft.

UNCLASSIFIED