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DESIGN CRITERIA FOR ROOF WASHDOWN

Phase II. Fallout Removal Studies on Typical Roofing Surfaces for Three Size Ranges of Particles (44 to 88 μ, 88 to 177 μ, and 590 to 1190 μ).

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ADMINISTRATIVE INFORMATION

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ABSTRACT

Fallout simulant particles ranging in size from 44 to 88, 88 to 177 and 590 to 1190 μ were deposited at a rate of approximately 2 grams/min/ft^2 for a period of 30 min 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. A residual mass of less than 10 % of the 590 to 1190 μ particles was obtained on aluminum shingles, composition shingles, roll roofing, corrugated metal and fiberglass epoxy laminated roof with a maximum of 3.5 gallons of water per minute per foot of roof width (gpm/ft) at a slope of 1:8 or greater. Thirty-five to forty-five percent of the 88 to 177 μ particles was retained on the corrugated metal at this same slope with a water flow of 3.5 gpm/ft of width. A residual of 5 % or less was obtained on roll roofing at a slope of 1:8 or greater with a water flow of 3.5 gpm/ft of width with both the 88 to 177 and the 590 to 1190 μ particles. With the same two particle sizes, a residual of 5 % or less was obtained on a fiberglass epoxy laminated roof with a maximum water flow of 1.0 gpm/ft of width at a slope of 1:12 or greater.

PREFACE

Extensive laboratory studies have been carried out to develop design criteria for roof washdown systems. Following studies of the basic mechanism of transporting particles in small-scale experiments, full-size roof planes were constructed. Typical roofing surfaces were installed on these planes to study washdown effectiveness in removing a wide range of fallout particle sizes.

Removal studies on particles ranging in size from 177 to 590 μ were reported previously in Reference 1. Removal effectiveness on 44 to 177 μ and 590 to 1190 μ diameter particles is discussed in this report.

A complete roof washdown design, based on the design criteria described here and in previous reports, will be developed and presented with cost estimates in a forthcoming report.

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FIGURES

FIGURES (cont'd)

TABLES

TABLES (Cont'd)

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Full-scale roof washdown studies were initiated at Camp Parks, Pleasanton, Calif., to provide design data for an operational washdown system. Phase I of these studies, Fallout Removal Studies on Typical Roofing Surfaces for the 177 to 350 μ and 350 to 590 μ particle size range, was reported in Reference 1. This present report, Phase II, gives the results of comparable tests on the 88 to 177 μ and 590 to 1190 μ particle size ranges and a limited number of tests on the 44 to 88 μ size particles.

1.2 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.

1.3 APPROACH

The washdown effectiveness in removing simulated fallout particles from typical roofing surfaces was studied under various conditions to

determine the optimum water flow rate and surface slope. Non-radioactive silica particles were used and the removal effectiveness was determined by gravimetric analytical methods. The test parameters included:

1. Test Surfaces: Aluminum shingles, composition shingles, fiberglass epoxy laminate, roll roofing, and corrugated metal roofing.

2. Water Flow rates:* Maximum, 7 gpm/ft of width; minimum, 0.5 gpm/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 particle sizes. To simplify these series of studies, the following five particle size ranges were selected.

Size	Diameter μ	Mass Median Diameter** μ	U.S. Bu. of Stds. Sieve No.
A	44 to 88	63	325 to 170
B	88 to 177	112	170 to 80
C	177 to 350	262	80 to 45
D	350 to 590	450	45 to 30
E	590 to 1190	910	30 to 16

Studies on sizes C and D were reported in Phase I report (Ref. 1) and tests using sizes A, B and E are presented in this report. Sieve analyses of the five sizes studied are given in Appendix A.

5. The simulant particles were deposited at a rate of approximately 2 grams/min/ft^2.

* All water flow rates in this report are given in gallons per minute per foot of roof width and will be abbreviated as gpm/ft.
**These were obtained from a plot of Sieve Analyses (Appendix A).

CHAPTER 2

TEST EQUIPMENT AND SURFACES

A brief description of the test equipment and surfaces is given in this section. For a more detailed description, see References 1 and 2.

At the completion of Phase I of these studies (Ref. 1), the aluminum shingles and composition shingles had become badly dented and worn and were replaced with new shingles which were obtained from the same source as the original materials. In order to differentiate between the original and replacement surfaces, the surfaces used during Phase I are called Installation I and the replacement surfaces used during Phase II are called Installation II. A series of runs with the same test conditions using particle sizes C and E simulant was made on both installations for comparison of the percent residual remaining on the two surfaces. Any differences in results would then be due to slight variations in the surfaces of the roofing materials and the installation.

2.1 TEST PLANE

The test surfaces were supported by rigid frames and were mounted on two tilt planes, each 24 ft wide by 48 ft long. The planes could be individually adjusted to any slope from 0 to 1:4 (Fig. 1) by a hydraulic system. Each plane was divided into three sections, to give a total of six testing areas each 8 ft wide by 48 ft long, with a different roofing surface on each of 5 sections. The sixth section was not used in Phase II studies.

The five surfaces studied in Phase II were:

1. Aluminum shingles* - commercial interlocking roofing.

   a. Installation I - Original surface used in Phase I studies - comparison tests made with Installation II.

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

b. Installation II - New surface installed for Phase II test.

2. Composition shingles - commercial roofing shingles. Installation I was replaced with installation II at the same time as the aluminum shingles test surface.

3. Fiberglass epoxy laminate - One sheet of fiberglass bonded to a plywood base with an epoxy laminating resin, covered with a brush coat of the laminating resin after the first coat had cured.*

4. Roll roofing - 90 lb mineral paper applied on a mop-tarred plywood base.

5. Corrugated galvanized steel - 2-1/2-in. corrugations with 1/2 in. trough depth.

2.2 THE WATER SYSTEM

A recirculating water system was used for these tests. This system consisted of a settling and filtration tank and piping for returning the water to the test surfaces (Reference 1). The washdown water was pumped from the tanks to pipe headers located across the 8-ft width at the top of each test surface. Flooding type nozzles** were used in the headers to create a continuous film of water on the surfaces.

2.3 FALLOUT DISPERSER

The fallout dispersal system consisted of 18 individual dispersers mounted over each of the two tilt planes at a height of approximately 24 ft above the test surfaces. During operation, a continuously metered amount of the particles was fed to the individual nozzles, where an air stream picked them up and blasted them against a deflector plate (Reference 2).

However, when the air pressure to the individual nozzles was held constant, the distribution patterns on the test surfaces varied when

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* Construction details are given in Ref. 1.
**"K" series nozzles, manufactured by Spraying Systems, Inc.

the different size particles were dispersed. Accordingly, the following air pressures to the nozzles were experimentally determined as being required to give approximately equivalent distribution patterns for each of the particle sizes.

Size A - 30 psi
B - 20 psi
C - 15 psi
D - 15 psi
E - 10 psi

The lower air pressure gave uniform coverage of the test surfaces with the larger particle sizes (C, D, and E) when 18 in. wide baffles were mounted at about 60° angles to the horizontal on all four sides of the 4 ft by 4 ft plywood backing panels of each disperser (Fig. 2). The higher air pressure was required on the small size particles (A and B) to give wider distribution and prevent high concentrations directly under the individual dispersers. To prevent excessive dispersion of the fine particles beyond the test surfaces at the higher air pressures, curtains were hung on the outside edge of the individual dispersers that were above the outer edges of the tilt planes. Polyethylene curtains 4 ft wide by 10 ft long (Fig. 3) on each of these dispersers proved to be the most satisfactory of the wide variety of sizes and methods of attachment that were tested.

CHAPTER 3

EXPERIMENTAL PROCEDURES

In all the washdown effectiveness studies, a fallout dispersal period of 30 min at a fallout rate of approximately 2 grams/min/ft^2 was used. This rate and the total amount deposited were used because they represent an extreme case which greatly exceeds the maximum that would be expected from a land surface nuclear detonation. The fallout dispersal was started after the washdown water was turned on, and the test surfaces were completely wetted. The washdown water flowed during the 30 min dispersal period and for an additional 30 min after the cessation of fallout. The particles removed from each test surface during this 1-hr period were collected in a 325-mesh sieve (Ref. 1). After the washdown period the sieves were replaced with clean ones, and the residual fallout simulant on the surfaces was removed by careful flushing with a garden hose.

The dry weight of the simulant fallout particles collected in the sieves was obtained by multiplication of the net wet weight of the particles by a ratio that was constant for each particle size. This net wet weight was obtained prior to the studies by submerging the sieves and contents in water, allowing them to drain for exactly 10 minutes, and then weighing them and subtracting the weight of the sieves. The ratio of the net wet weight to the dry weight of the particles was determined in calibration runs to be 1.25 for the 590 to 1190 μ particles (Size E), and 1.27 for both the 88 to 177 μ particles (Size B) and the 44 to 88 μ particles (Size A).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 REMOVAL OF SIZE B AND E FALLOUT PARTICLES

The washdown effectiveness results for five surfaces at the various slopes with different water flow rates are plotted as percent residual vs water flow rate, and are shown in Figs. 4 through 8 for Size E particles (590 to 1190 μ), and Figs. 9 through 13 for Size B particles (88 to 177 μ). The tabulated results are given in Appendix B.

Corrugated galvanized steel showed the highest percentage of residual mass remaining of the 5 surfaces tested. A flow of at least 3 gpm/ft of width was required on this surface, at a 1:8 slope, to reduce the residual mass of Size E particles to less than 10 %. At slopes of 1:6 and 1:4, however, a flow rate of 1.5 gpm/ft of width was sufficient to reduce the residual to less than 10 %. With Size B particles on the corrugated, the residual mass was approximately 25 to 30 % of the total deposit with a flow of 7 gpm/ft of width at all three slopes studied. The high residual with the fine particles is due to the fallout sticking to the crest of the corrugations, whereas the larger particles roll off. It should also be noted for this surface that the effect of slope on residual is very small. In other words, increasing the slope from 1:8 to 1:4 has little effect on the removal effectiveness.

A flow rate of approximately 2 gpm/ft of width is sufficient to give 10 % or less residual on all the other surfaces except the aluminum shingle surface at a 1:8 or higher slope. The aluminum shingles at a slope of 1:8 required a flow of 3.5 gpm/ft of width to reduce the Size E particle residual to 10 %, while the same flow at the same slope removed only 70 % of the Size B particles. The washdown was more effective on the fiberglass epoxy surface than on any of the other surfaces. A flow rate of 2 gpm/ft of width gave a 99 % removal of the Size B particles at slopes of 1:6 or higher and 1 % removal of the Size E particles at a slope of 1:8 or higher.

4.2 REMOVAL OF SIZE A FALLOUT PARTICLES

The limited number of tests conducted using Size A particles (44-88 μ) are given in Table 1. The flow rates in Table 1 were selected as sufficient to give less than 10 % residual.

No definite conclusions were drawn from the test data for Size A particles because too few tests were run. Generally, however, the

TABLE 1

Washdown Removal Efficiency with Size A Particles (44 to 88 μ) Mass Median Diameter - 62 μ

	1:4 Slope		1:8 Slope		1:24 Slope	
	Residual (%)	Flow Rate gpm/ft*	Residual (%)	Flow Rate gpm/ft*	Residual (%)	Flow Rate gpm/ft*
Aluminum Shingles (Installation II)	4.2	3.0	10.5	5.3	-	-
Composition Shingles (Installation II)	10.3	3.0	9.1	5.0	-	-
Fiberglass Epoxy Laminate	0.7	2.0	0.5	2.0	4.4	2.0
Roll Roofing	4.0	3.0	8.2	3.0	15.6	5.5
Corrugated Steel	56.1	2.0	-	-	-	-

*Flow rate in gallons per minute per foot of width.

percentage of residual mass was slightly higher than for Size B particles for a given set of conditions.

4.3 VARIATIONS IN ROOFING INSTALIATIONS

The comparison of two separate installations of aluminum shingles and composition shingles are shown in Figs. 14 through 17 for Size C and Size E particles. This is given to show how the washdown effectiveness may vary between new and used (or well weathered) installations of the same roofing surface. Composition shingles, Installation II, retained a smaller percentage of both particle Sizes C and E than Installation I at all slopes (Figs. 14 and 15). Aluminum shingles, Installation II, however, gave a lower percentage residual at the 1:4 slope only. At the 1:6 and 1:8 slope this trend showed a reversal in most cases (Figs. 16 and 17). The variations in removal results are due to slight variations in the surfaces of the roofing material and the installation. The variations between the two surfaces serves to point out the importance of using a sizable safety factor in designing an operational washdown system.

4.4 APPLICATION OF RESULTS

It is assumed by the authors that a 10 % residual mass on the roof (reduction factor (R.F.) of 10) is the maximum amount that should be acceptable; that less than 5 % residual is desirable (R.F. of 20); and that a 1 % or less residual (R.F. of 100) should be the design objective.

In order to determine the minimum water flow required to obtain these percent residuals for the various test surfaces and slopes, data taken from Figs. 4 through 17 was plotted in Figs. 18 through 24. Figures 18-20 show the minimum water flow required to obtain 10 % residual of the fallout particles on the test surfaces with the particle sizes tested at the slopes shown. Figures 21 through 23 show the minimum water flow required for 5 % residual mass, and Fig. 24 the minimum water flow required to obtain 1 % residual. Points on the graphs are shown where data was obtained. The absence of a point indicates that the percent residual was higher than the specified amount for the test conditions or that no test was made with that particular set of conditions.

CHAPTER 5

CONCLUSIONS

5.1 CONCLUSIONS

A slope of at least 1:8 is required on aluminum and composition shingles, and a water flow rate of at least 3.4 and 2.1 gpm/ft of width, respectively, are required to reduce the Size E particle residual to less than 10 %. A flow rate of 5.8 and 5.0 gpm/ft of width is required on the aluminum and composition shingles, respectively, to reduce the particle Size B residual to less than 10 %.

Ten percent residual can be accomplished on the roll roofing at a slope as low as 1:12, with a flow of 3.1 gpm/ft of width for the Size E particles and 3.5 gpm/ft of width for the Size B particles.

The fiberglass-reinforced epoxy roof required a flow rate of only 1.5 gpm/ft of width to give 10 % residual at slopes as low as 1:24 with both particle sizes.

The Size E particles can be reduced to less than 10 % on corrugated metal with a flow of 3 gpm/ft of width or less, at slopes of 1:8 or higher. The Size B particles, however, gave a residual of 24 % at a slope of 1:4 with a flow of 7 gpm/ft of width.

5.2 RECOMMENDATIONS

It is recommended that (1) studies be made of methods of applying the washdown water to the roof through the use of special nozzles and placement of same, (2) a comparative cost study be made of the roof washdown countermeasure vs roof shielding required to provide the same dosage reduction in the interior of a building.

Fig. 1 Test Plane Raised to a 1:4 Slope

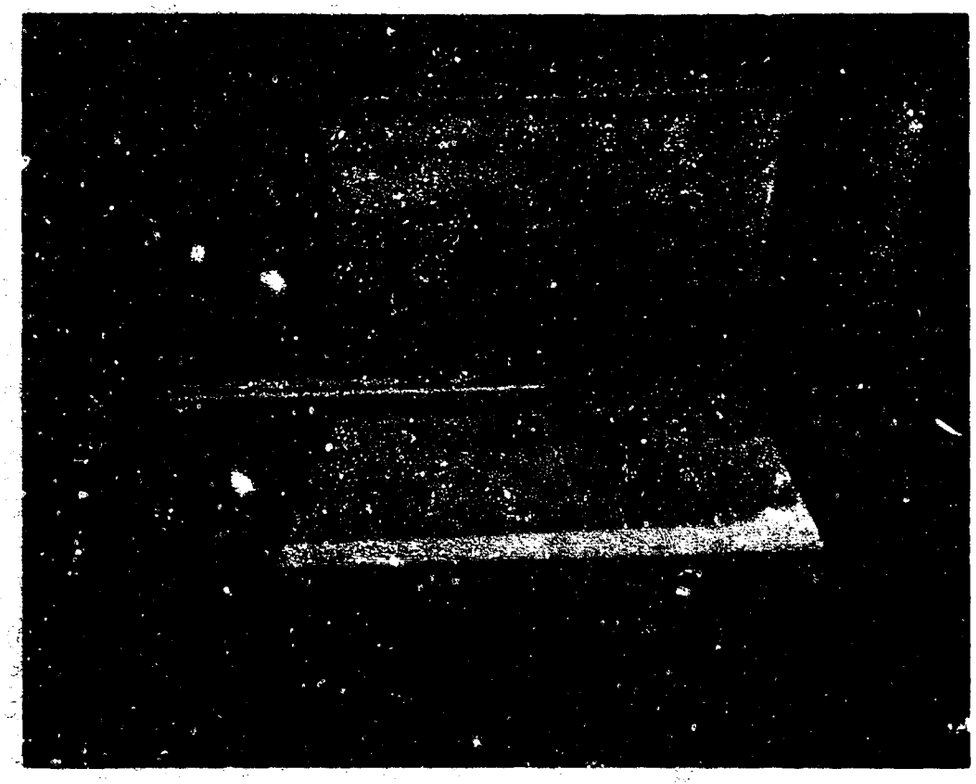


Fig. 2 Individual Disperser Modified with Side Baffles

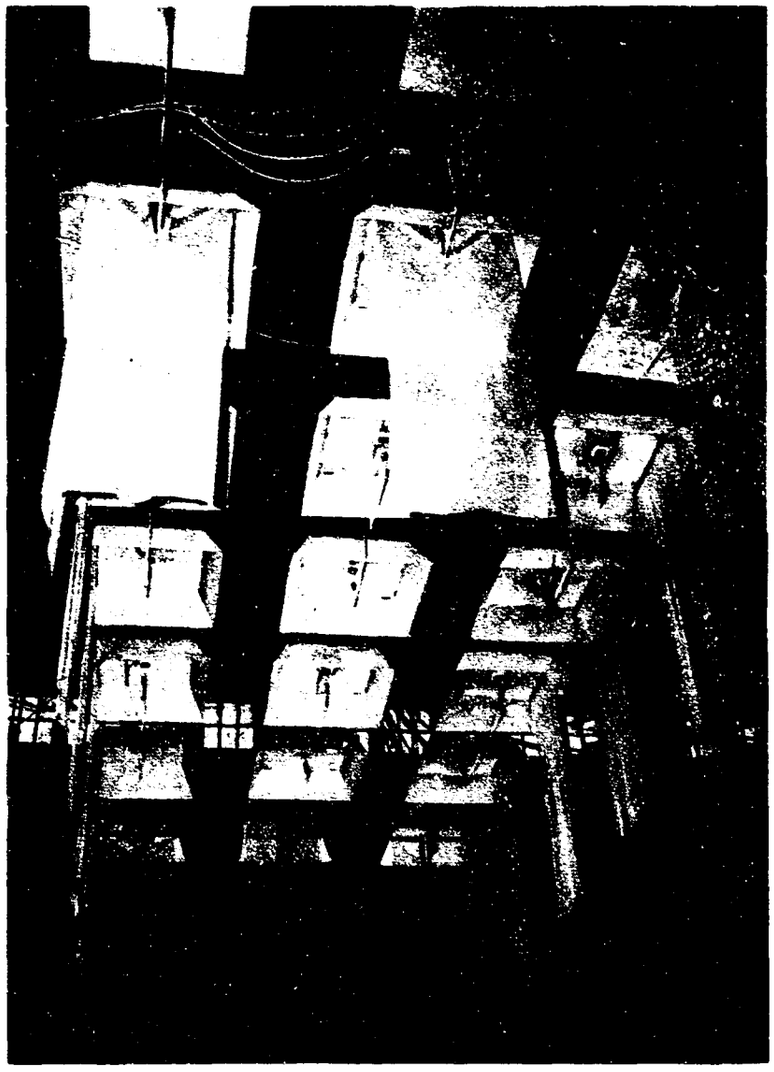
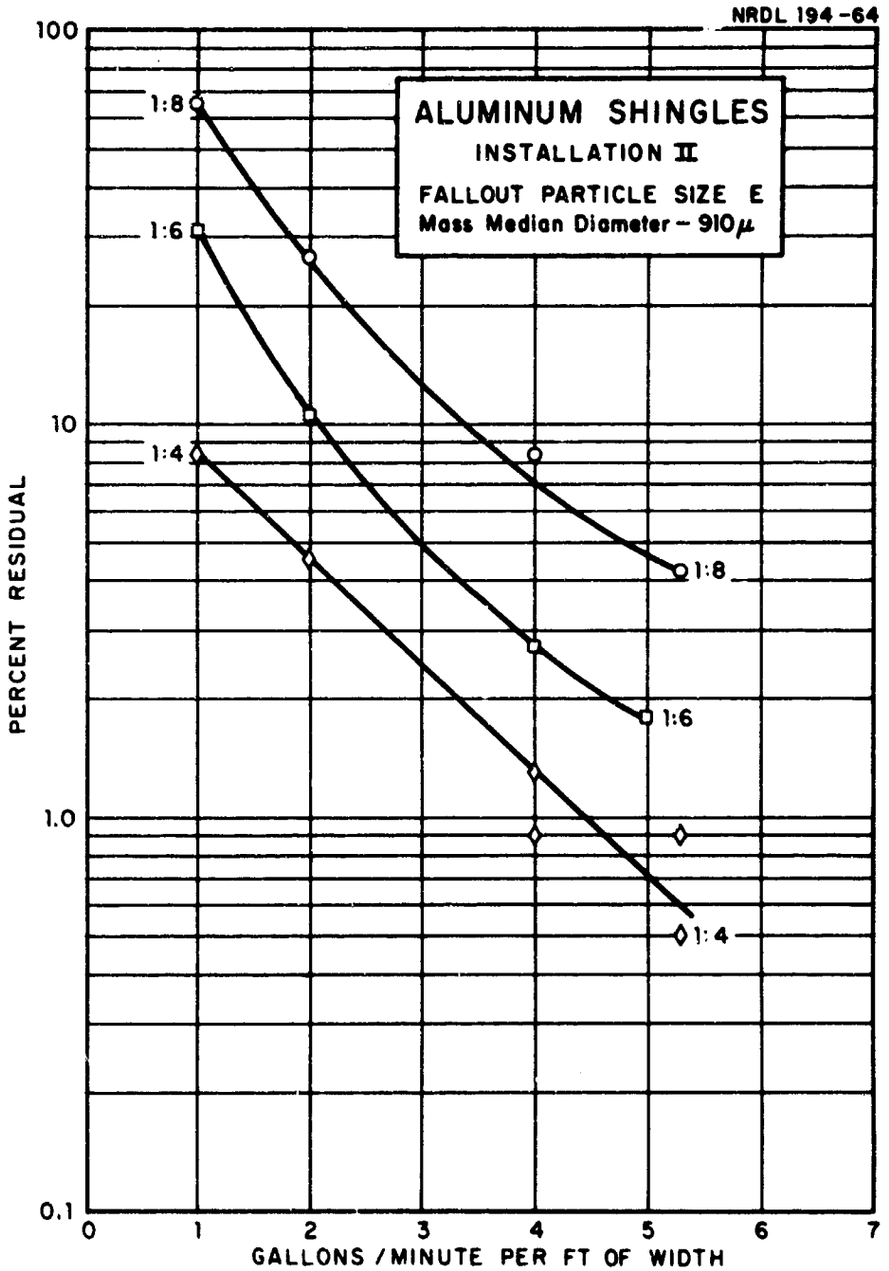


Fig. 3 Fallout Dispersers with Polyethylene Deflector Curtains Mounted Above a Test Plane

Figs. 4-13 Washdown Effectiveness for Verious Conditions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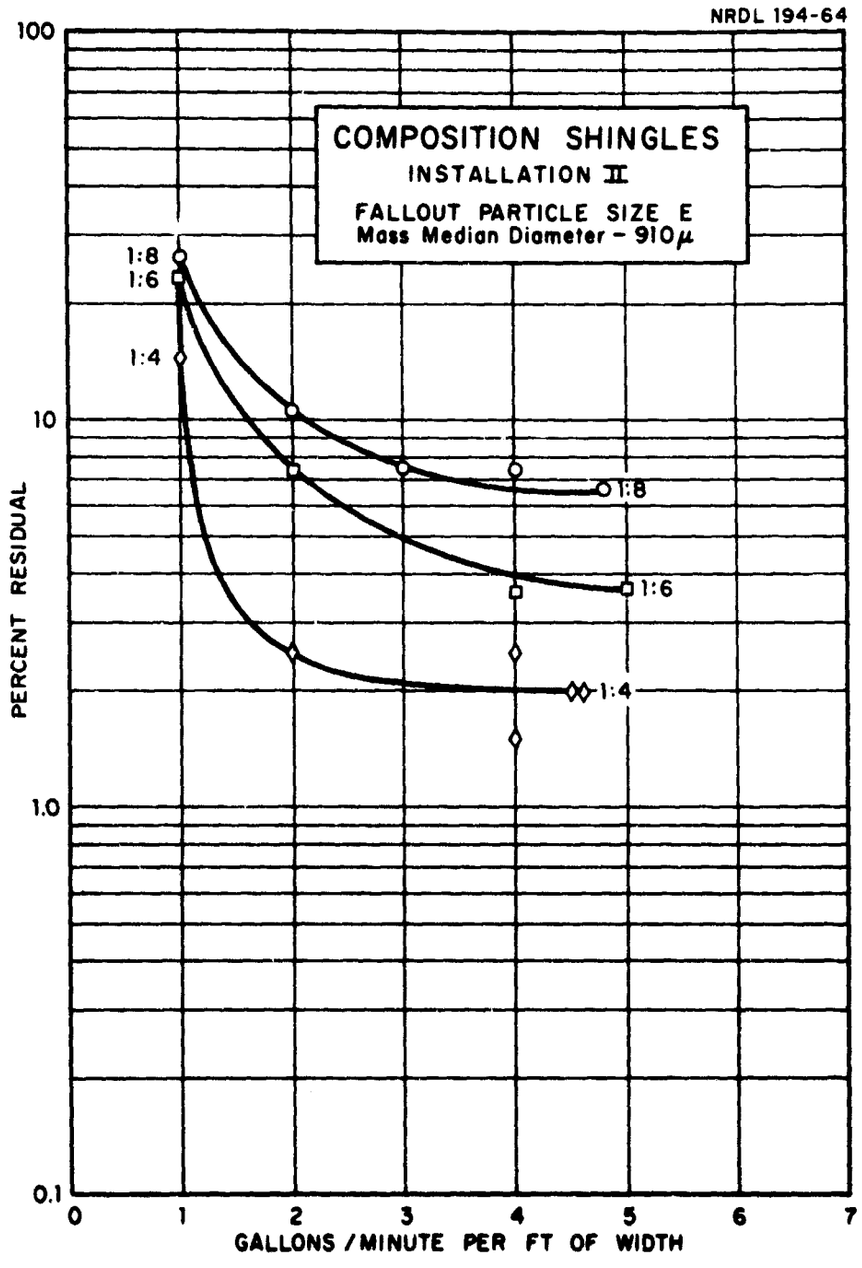
ALUMINUM SHINGLES
INSTALLATION II
FALLOUT PARTICLE SIZE E
Mass Median Diameter – 910μ
1:8
1:6
1:4
100
10
1.0
0.1
PERCENT RESIDUAL
0
1
2
3
4
5
6
7
GALLONS / MINUTE PER FT OF WIDTH

Fig. 4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COMPOSITION SHINGLES
INSTALLATION II
FALLOUT PARTICLE SIZE E
Mass Median Diameter - 910μ
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1:6
1:4
100
10
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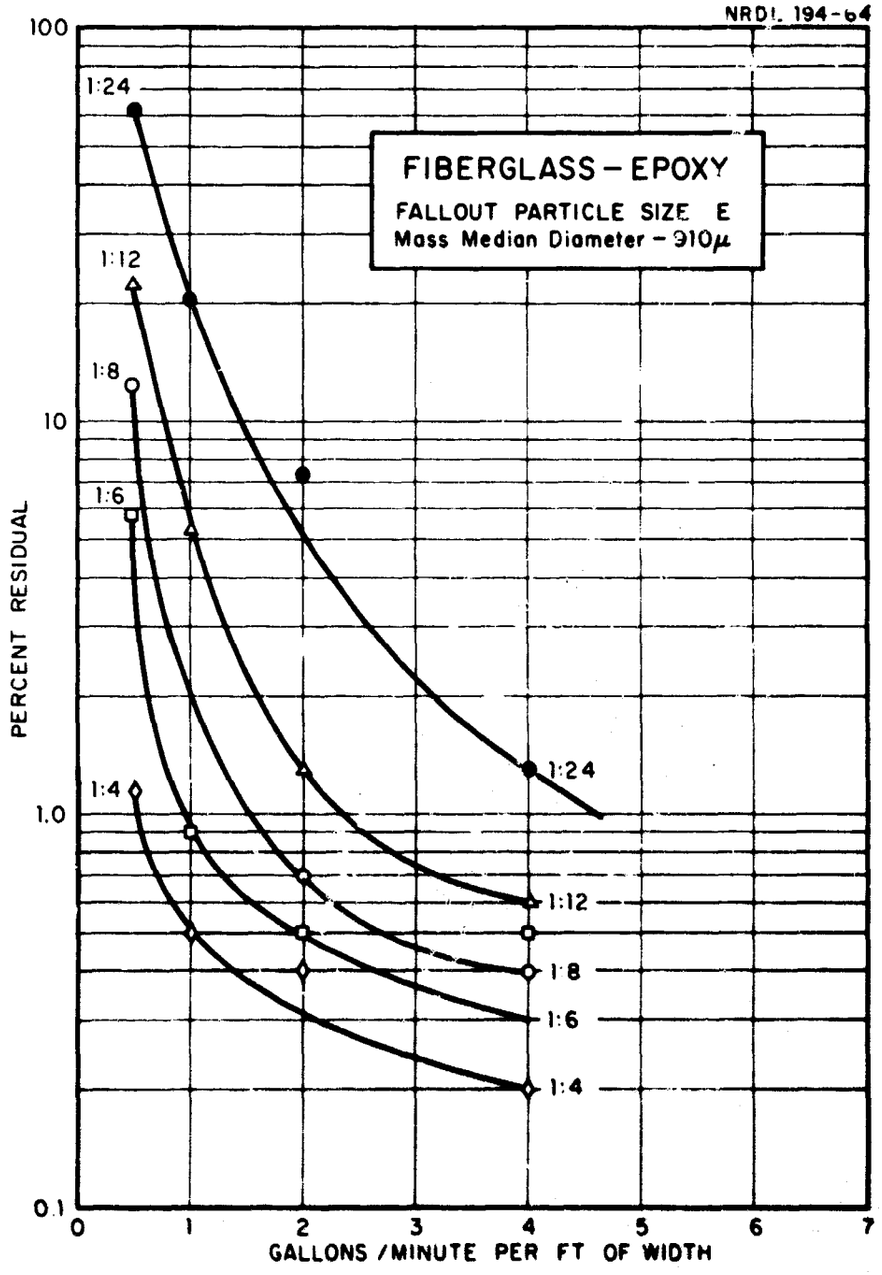
PERCENT RESIDUAL
0
1
2
3
4
5
6
7
GALLONS / MINUTE PER FT OF WIDTH

Fig. 5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FIBERGLASS – EPOXY
FALLOUT PARTICLE SIZE E
Mass Median Diameter – 910μ
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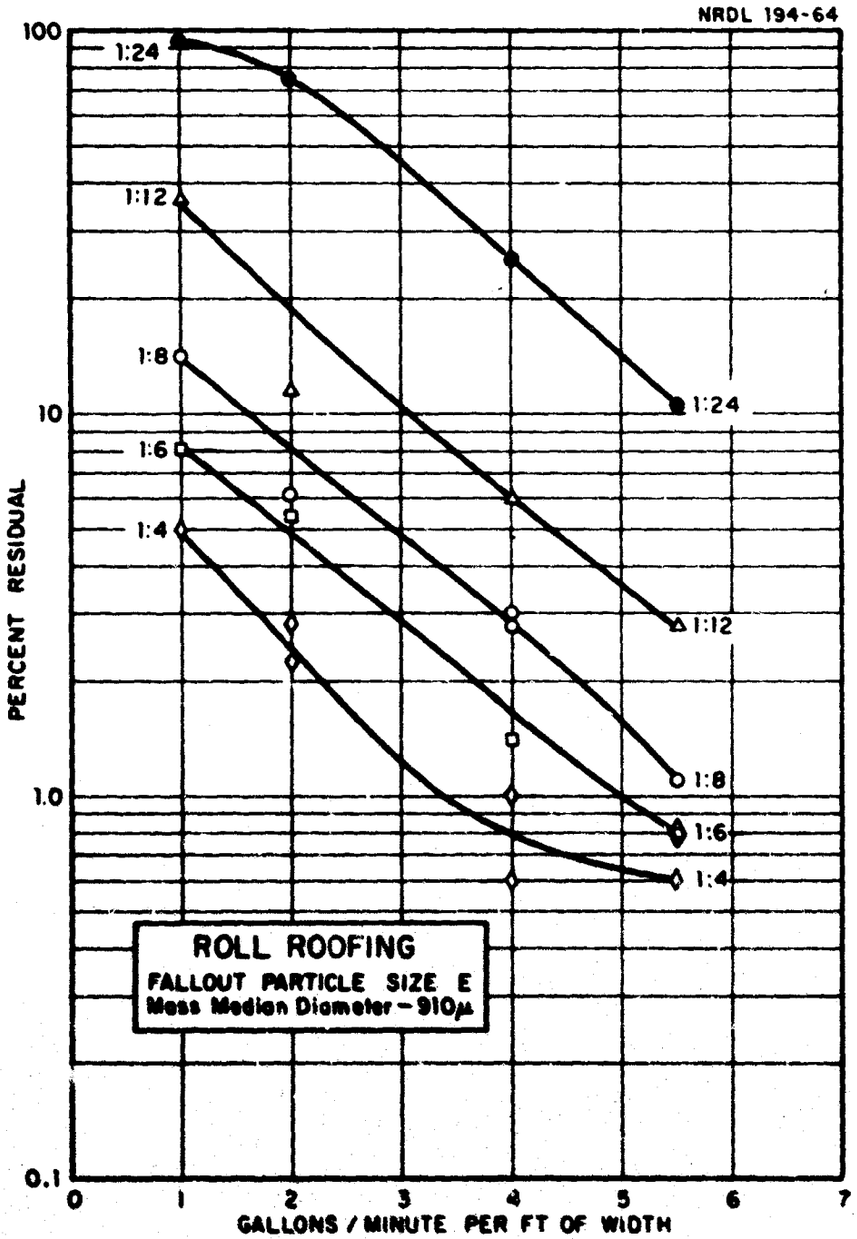
1:12
1:8
1:6
1:4
100
10
1.0
0.1
PERCENT RESIDUAL
0
1
2
3
4
5
6
7
GALLONS / MINUTE PER FT OF WIDTH

Fig. 6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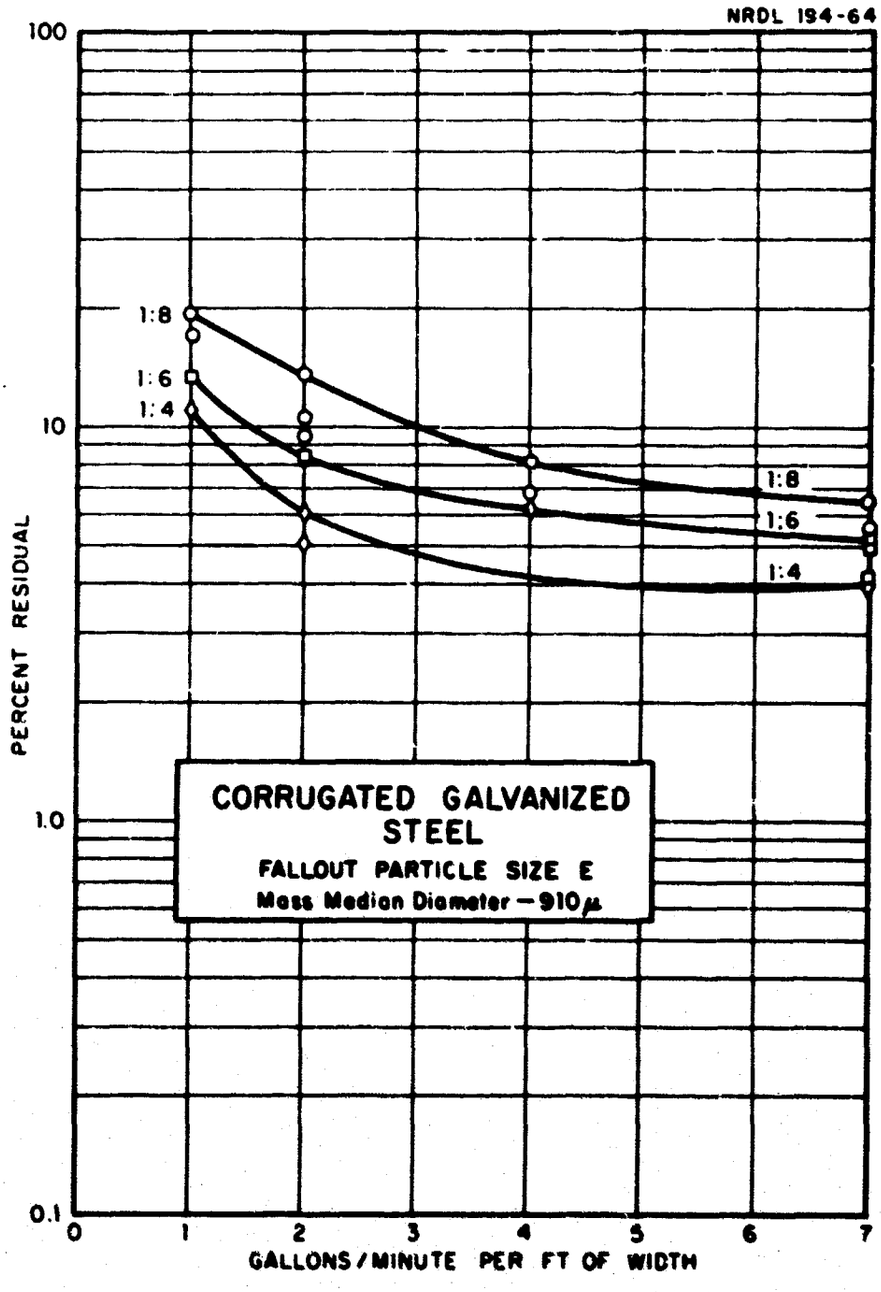
100
10
1.0
0.1
PERCENT RESIDUAL
1:24
1:12
1:8
1:6
1:4
ROLL ROOFING
FALLOUT PARTICLE SIZE E
Mass Median Diameter – 910μ
0
1
2
3
4
5
6
7
GALLONS / MINUTE PER FT OF WIDTH

Fig. 7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100
10
1.0
0.1
PERCENT RESIDUAL
1:8
1:6
1:4
1:8
1:6
1:4
CORRUGATED GALVANIZED STEEL
FALLOUT PARTICLE SIZE E
Mass Median Diameter — 910μ
0
1
2
3
4
5
6
7
GALLONS / MINUTE PER FT OF WIDTH

Fig. 8

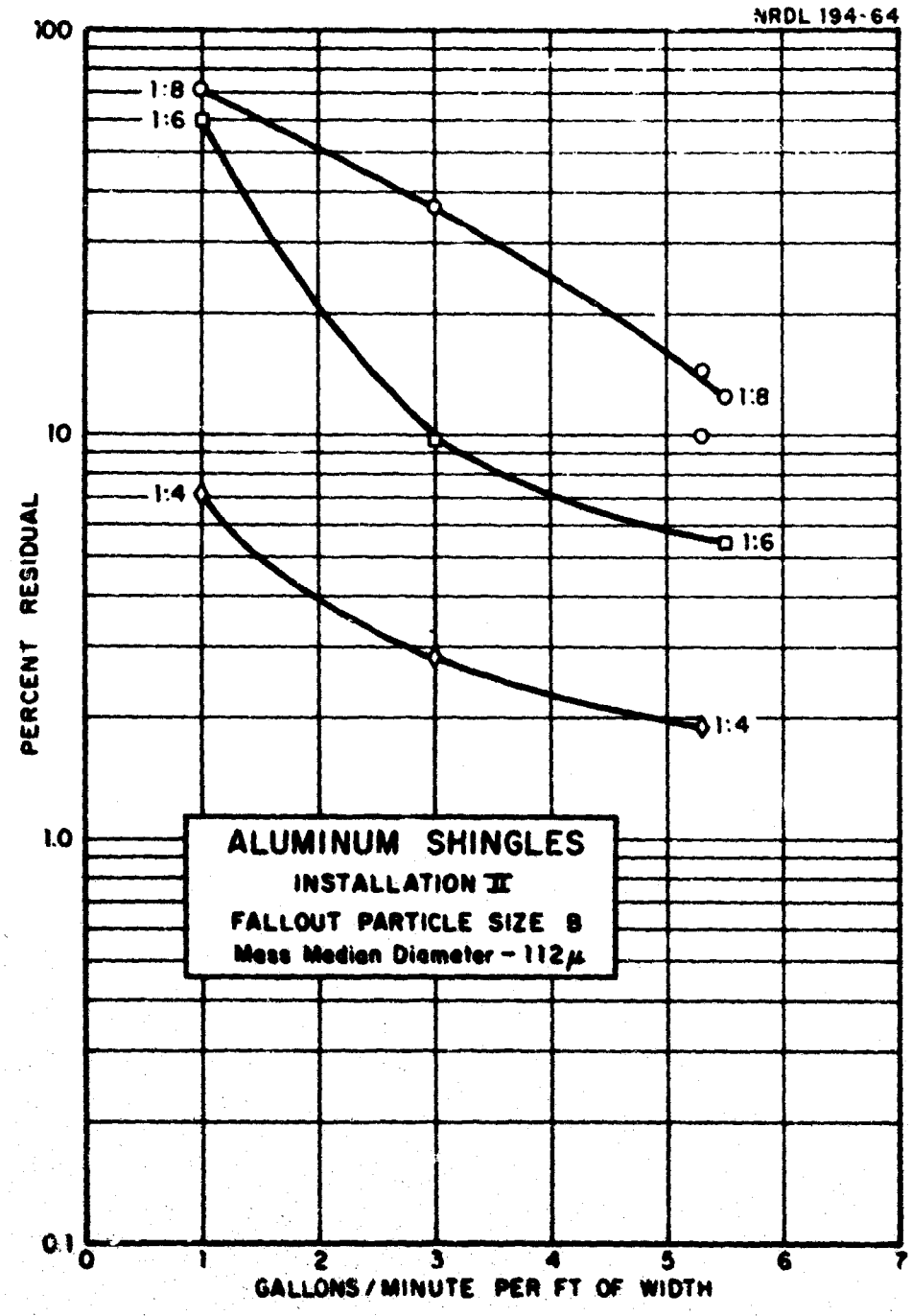
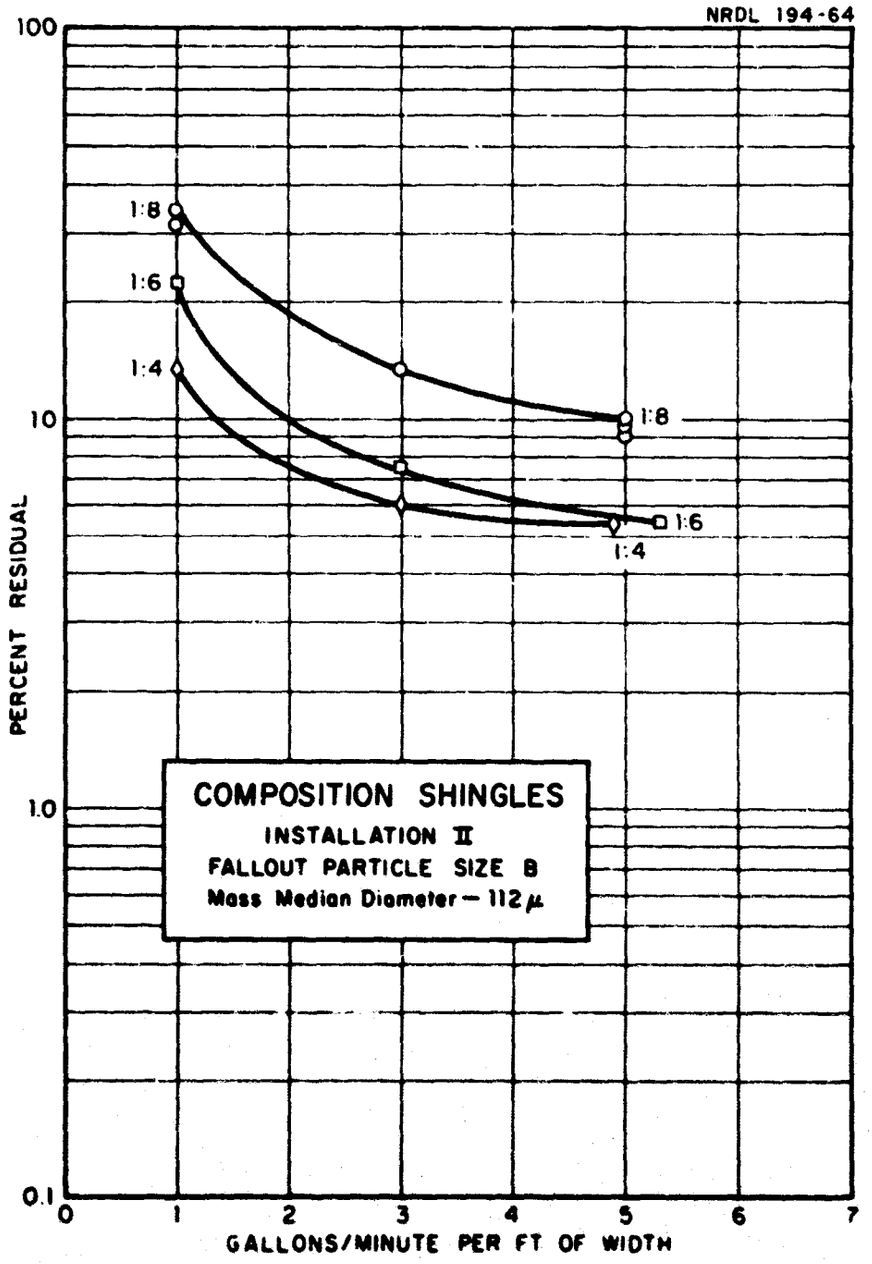

NRDL 194-64
100
10
1.0
0.1
PERCENT RESIDUAL
1:8
1:6
1:4
1:8
1:6
1:4
ALUMINUM SHINGLES
INSTALLATION II
FALLOUT PARTICLE SIZE B
Mass Median Diameter - 112μ
0
1
2
3
4
5
6
7
GALLONS / MINUTE PER FT OF WIDTH

Fig. 9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100
10
1.0
0.1
PERCENT RESIDUAL
1:8
1:6
1:4
1:8
1:6
1:4
COMPOSITION SHINGLES
INSTALLATION II
FALLOUT PARTICLE SIZE B
Mass Median Diameter — 112 μ
0
1
2
3
4
5
6
7
GALLONS/MINUTE PER FT OF WIDTH

Fig. 10

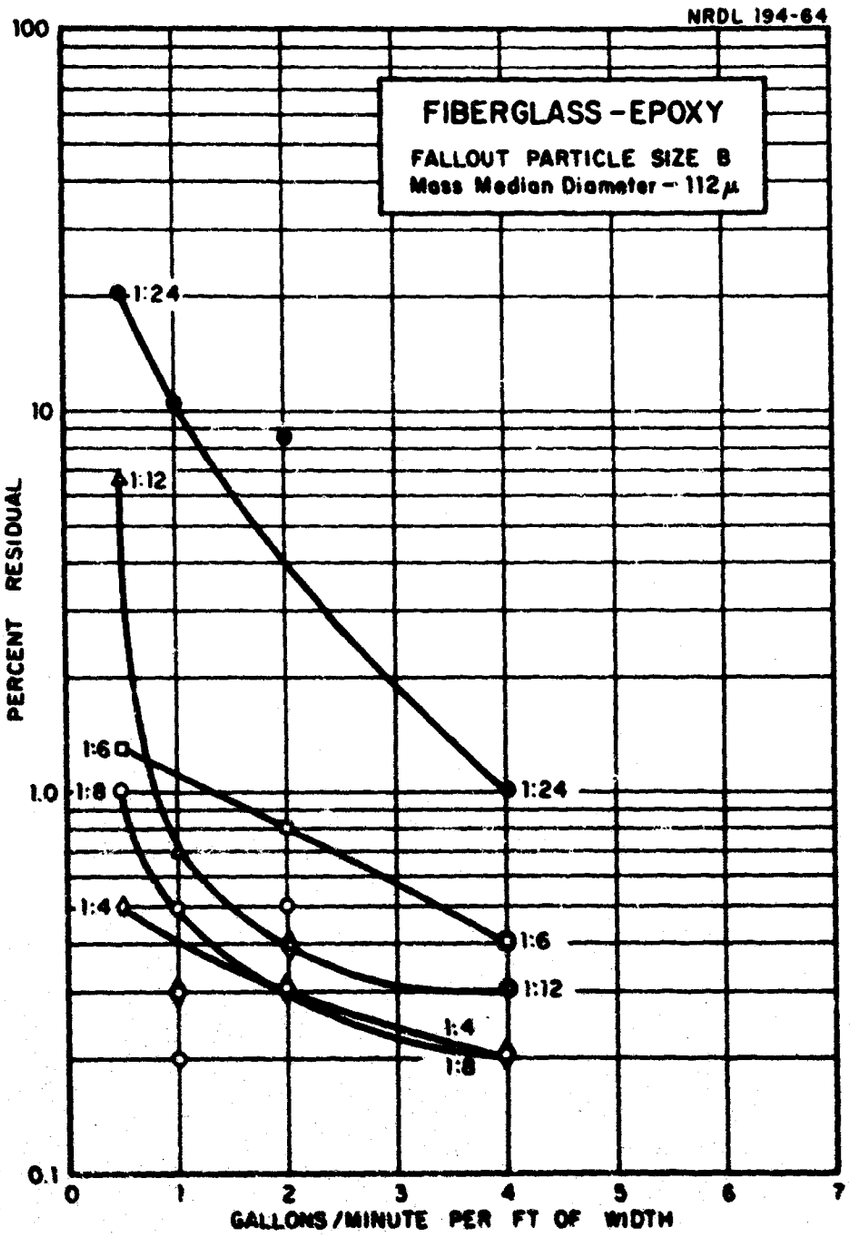

NRDL 194-64
FIBERGLASS - EPOXY
FALLOUT PARTICLE SIZE B
Mass Median Diameter - 112 μ
100
10
1.0
0.1
PERCENT RESIDUAL
1:24
1:12
1:6
1:8
1:4
0
1
2
3
4
5
6
7
GALLONS / MINUTE PER FT OF WIDTH

Fig. 11

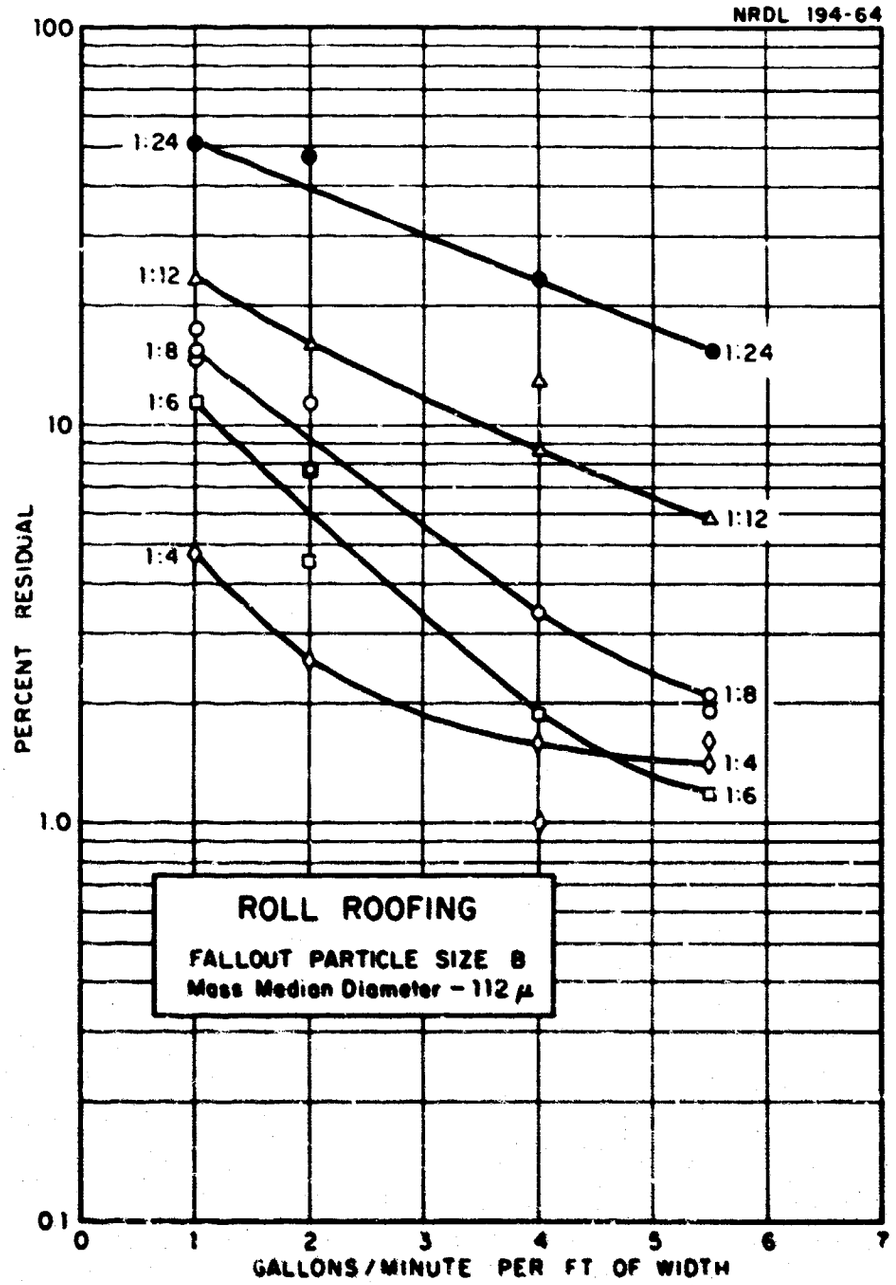

NRDL 194-64
100
10
1.0
0.1
PERCENT RESIDUAL
1:24
1:12
1:8
1:6
1:4
ROLL ROOFING
FALLOUT PARTICLE SIZE B
Mass Median Diameter – 112 μ
0
1
2
3
4
5
6
7
GALLONS / MINUTE PER FT OF WIDTH

Fig. 12

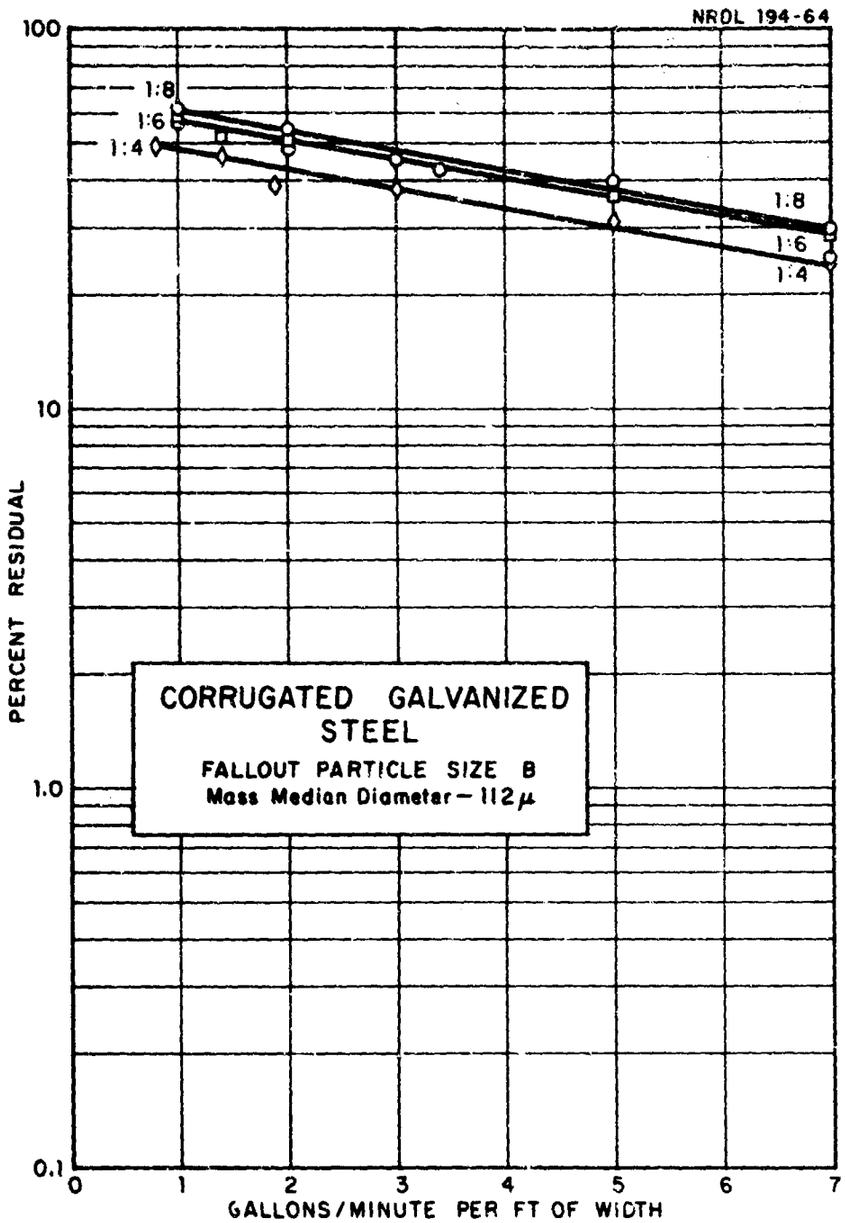
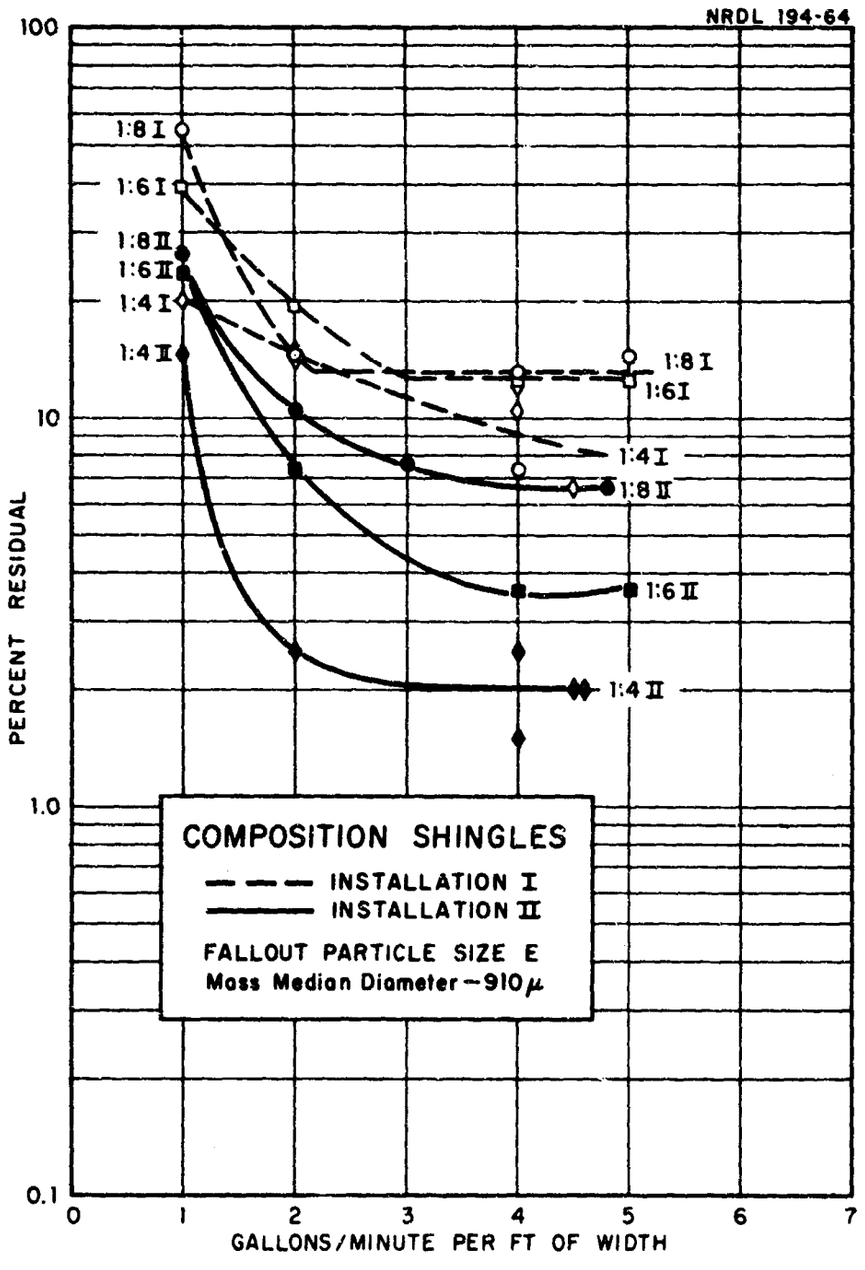

NRDL 194-64
100
10
1.0
0.1
PERCENT RESIDUAL
1:8
1:6
1:4
1:8
1:6
1:4
CORRUGATED GALVANIZED STEEL
FALLOUT PARTICLE SIZE B
Mass Median Diameter – 112 μ
0
1
2
3
4
5
6
7
GALLONS/MINUTE PER FT OF WIDTH

Fig. 13

Figs. 14-17 Washdown Effectiveness on New and Weathered Roofing Surfaces


NRDL 194-64
100
10
1.0
0.1
PERCENT RESIDUAL
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1:6 I
1:8 II
1:6 II
1:4 I
1:4 II
1:8 I
1:6I
1:4 I
1:8 II
1:6 II
1:4 II
COMPOSITION SHINGLES
INSTALLATION I
INSTALLATION II
FALLOUT PARTICLE SIZE E
Mass Median Diameter—910 μ
0
1
2
3
4
5
6
7
GALLONS/MINUTE PER FT OF WIDTH

Fig. 14

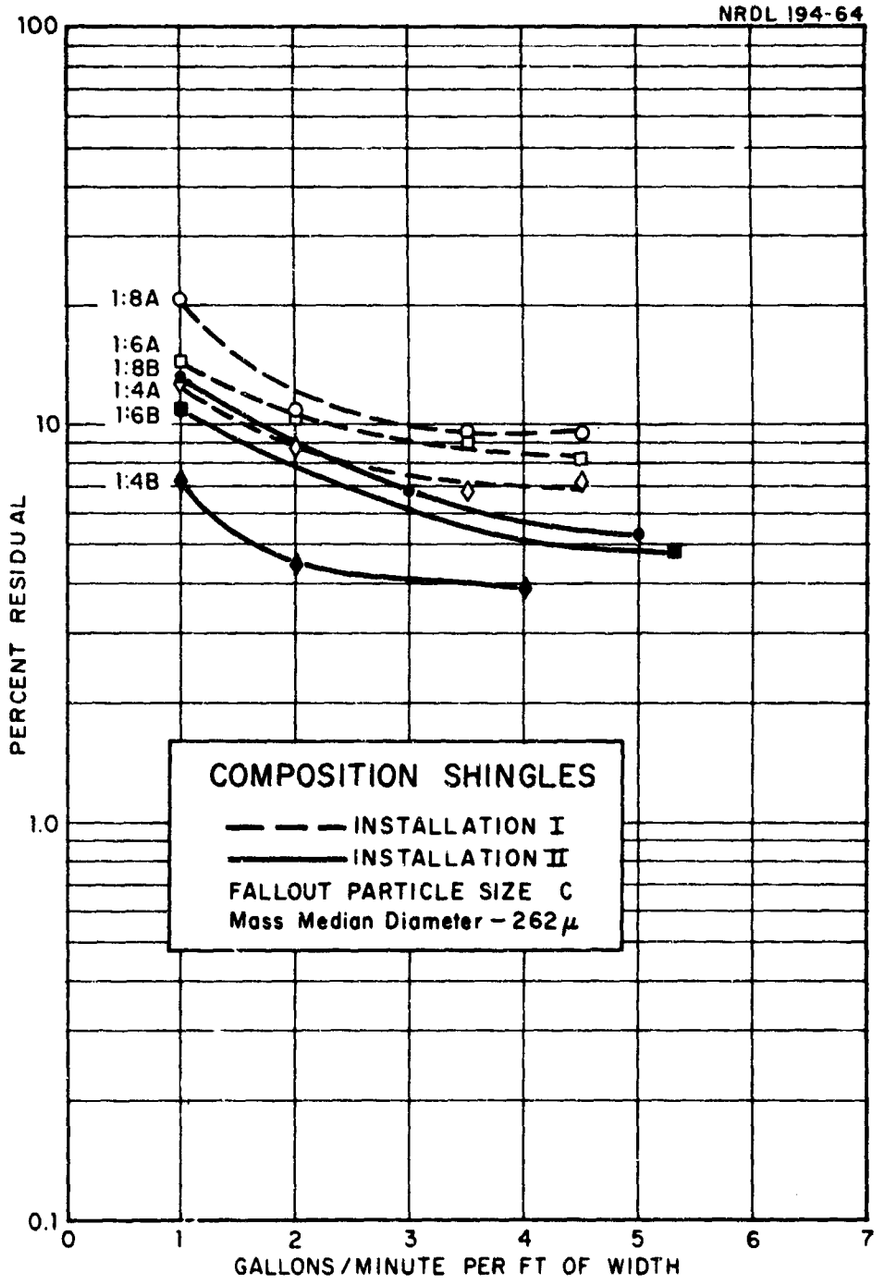
NRDL 194-64
100
10
1.0
0.1
PERCENT RESIDUAL
1:8A
1:6A
1:8B
1:4A
1:6B
1:4B
COMPOSITION SHINGLES
INSTALLATION I
INSTALLATION II
FALLOUT PARTICLE SIZE C
Mass Median Diameter – 262 μ
0
1
2
3
4
5
6
7
GALLONS / MINUTE PER FT OF WIDTH

Fig. 15

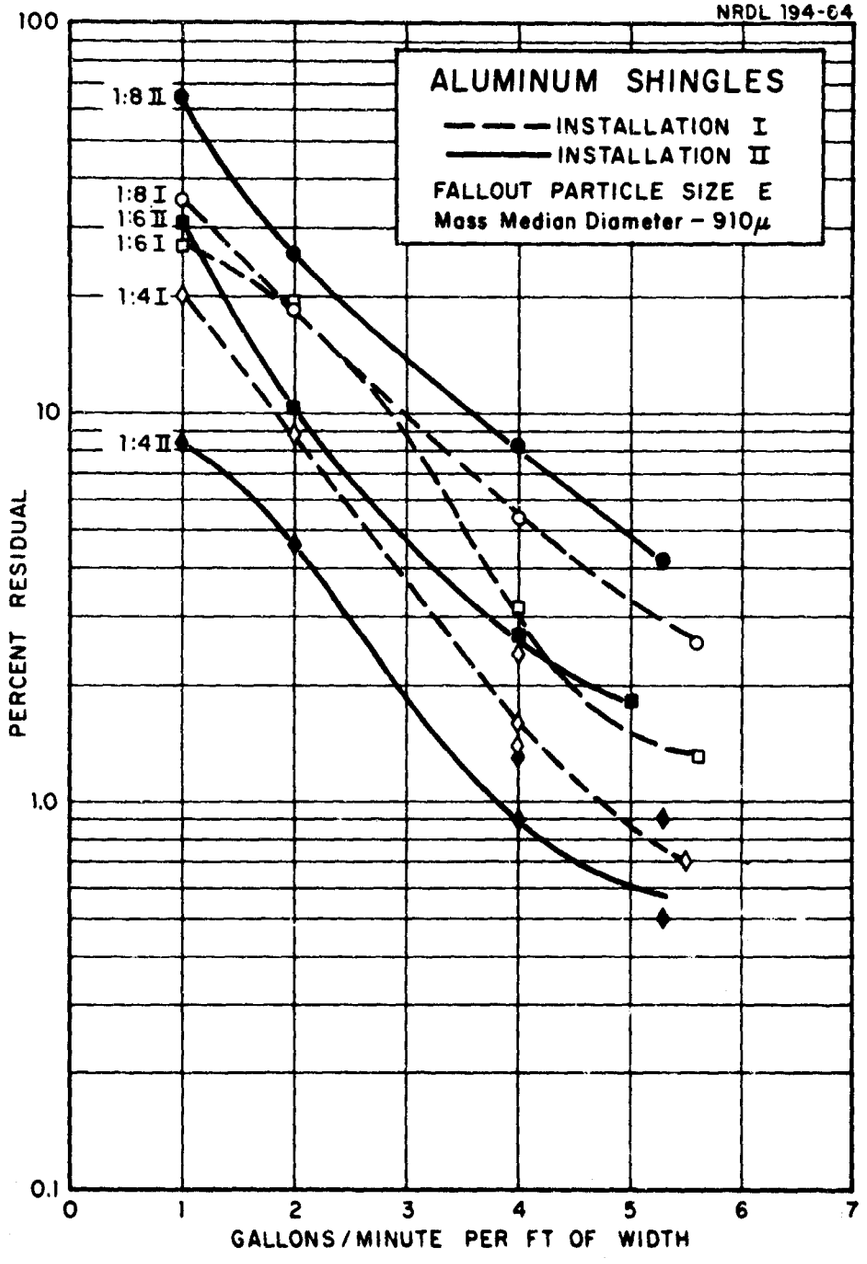
NRDL 194-64
ALUMINUM SHINGLES
INSTALLATION I
INSTALLATION II
FALLOUT PARTICLE SIZE E
Mass Median Diameter – 910μ
1:8 II
1:8 I
1:6 II
1:6 I
1:4 I
1:4 II
100
10
1.0
0.1
PERCENT RESIDUAL
0
1
2
3
4
5
6
7
GALLONS / MINUTE PER FT OF WIDTH

Fig. 16

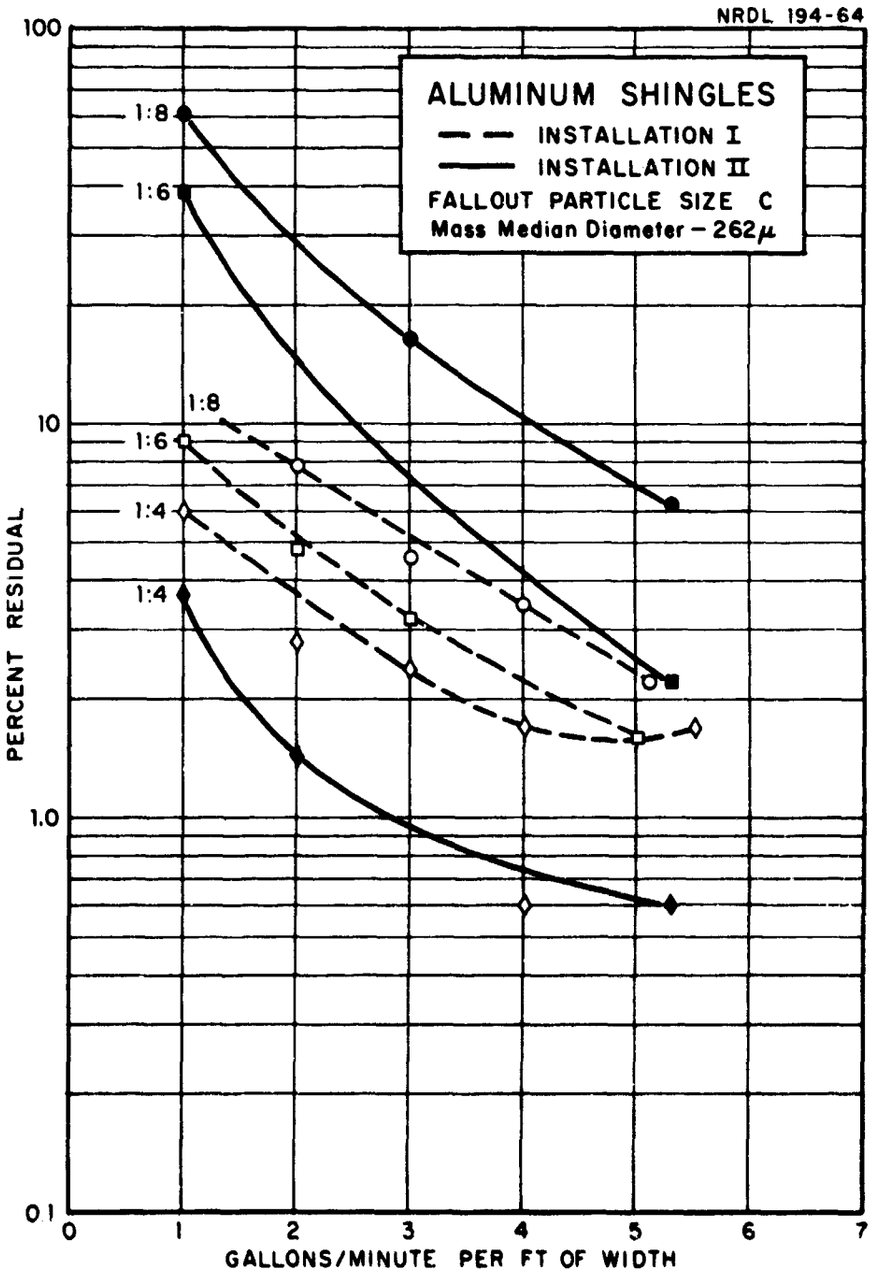
NRDL 194-64
ALUMINUM SHINGLES
INSTALLATION I
INSTALLATION II
FALLOUT PARTICLE SIZE C
Mass Median Diameter – 262μ
1:8
1:6
1:8
1:6
1:4
1:4
100
10
1.0
0.1
PERCENT RESIDUAL
0
1
2
3
4
5
6
7
GALLONS/MINUTE PER FT OF WIDTH

Fig. 17

Figs. 18-24 Conditions for Achieving Various Percentages of Residual Mass

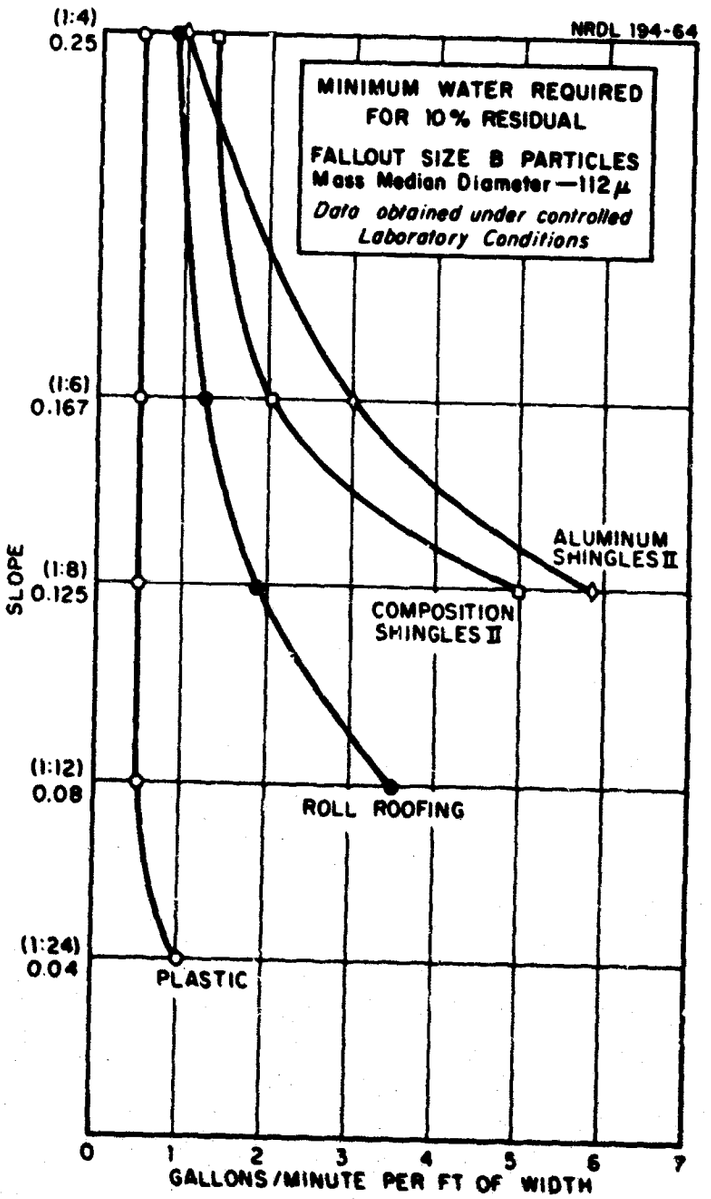
NRDL 194-64
MINIMUM WATER REQUIRED FOR 10% RESIDUAL
FALLOUT SIZE B PARTICLES
Mass Median Diameter—112 μ
Data obtained under controlled Laboratory Conditions
(1:4)
0.25
(1:6)
0.167
(1:8)
0.125
(1:12)
0.08
(1:24)
0.04
SLOPE
ALUMINUM SHINGLES II
COMPOSITION SHINGLES II
ROLL ROOFING
PLASTIC
0
1
2
3
4
5
6
7
GALLONS/MINUTE PER FT OF WIDTH

Fig. 18

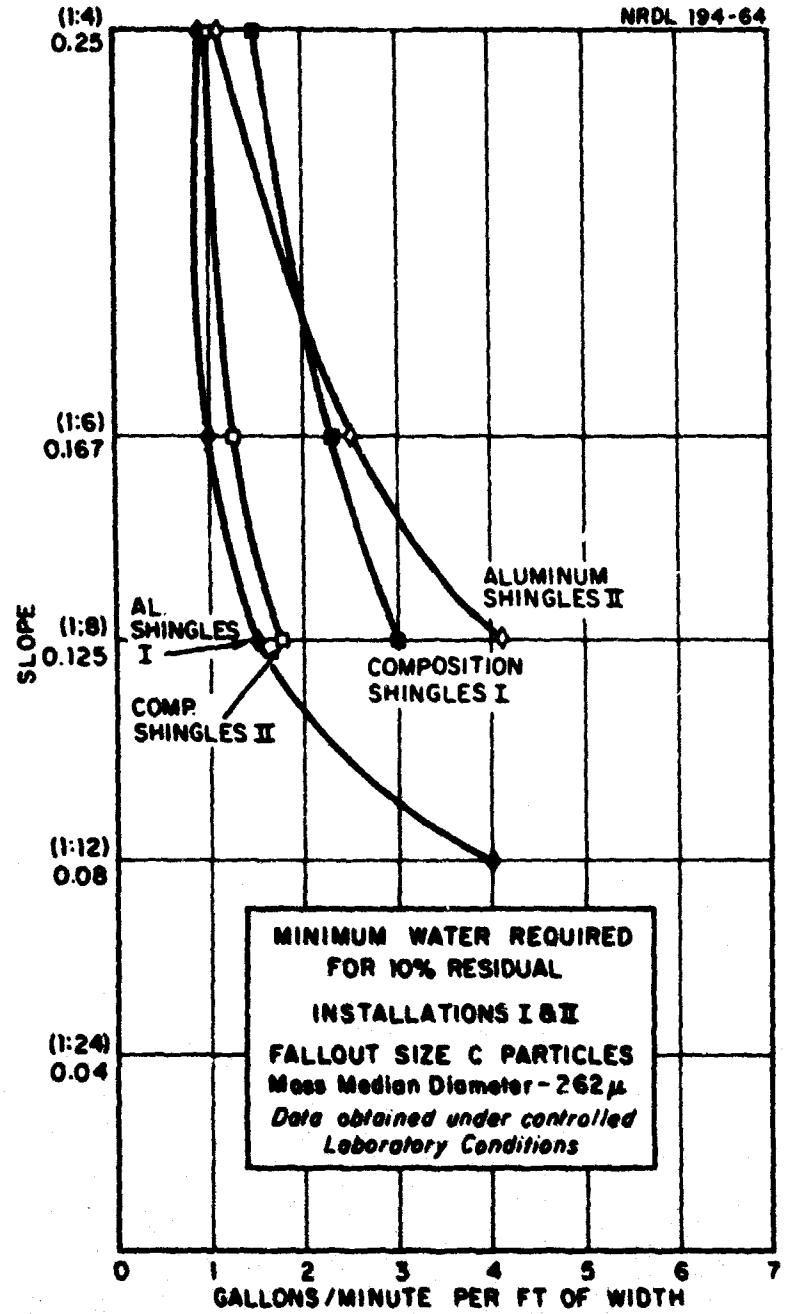
NRDL 194-64
(1:4)
0.25
(1:6)
0.167
(1:8)
0.125
(1:12)
0.08
(1:24)
0.04
SLOPE
AL. SHINGLES I
COMP. SHINGLES II
COMPOSITION SHINGLES I
ALUMINUM SHINGLES II
MINIMUM WATER REQUIRED FOR 10% RESIDUAL
INSTALLATIONS I & II
FALLOUT SIZE C PARTICLES
Mass Median Diameter - 262 μ
Data obtained under controlled Laboratory Conditions
0
1
2
3
4
5
6
7
GALLONS/MINUTE PER FT OF WIDTH

Fig. 19

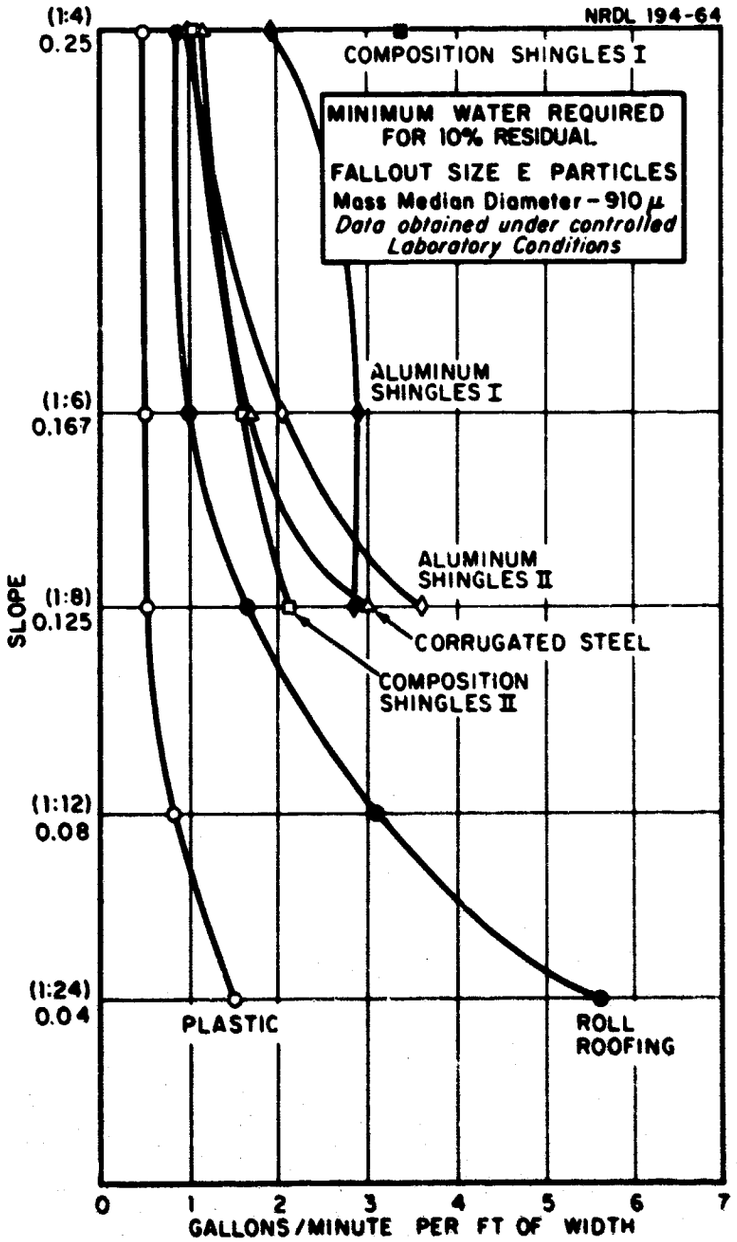
NRDL 194-64
(1:4)
0.25
(1:6)
0.167
(1:8)
0.125
(1:12)
0.08
(1:24)
0.04
SLOPE
COMPOSITION SHINGLES I
MINIMUM WATER REQUIRED FOR 10% RESIDUAL
FALLOUT SIZE E PARTICLES
Mass Median Diameter - 910 μ
Data obtained under controlled Laboratory Conditions
ALUMINUM SHINGLES I
ALUMINUM SHINGLES II
CORRUGATED STEEL
COMPOSITION SHINGLES II
PLASTIC
ROLL ROOFING
0
1
2
3
4
5
6
7
GALLONS/MINUTE PER FT OF WIDTH

Fig. 20

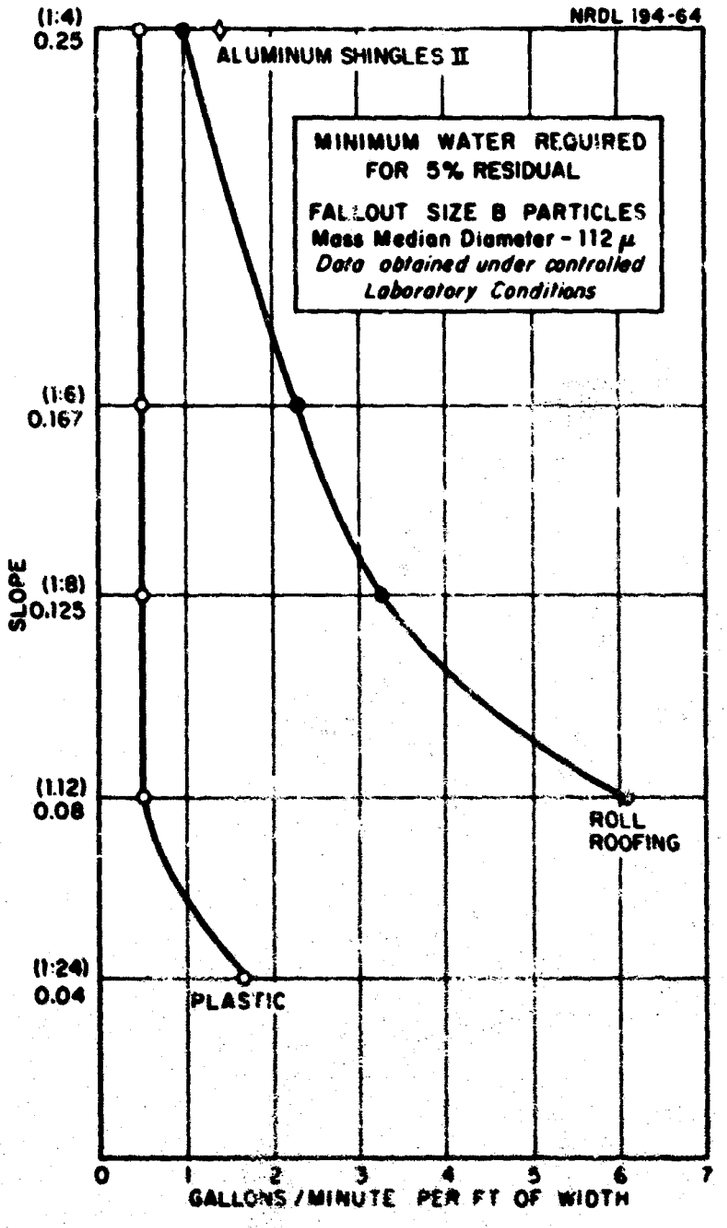
NRDL 194-64
ALUMINUM SHINGLES II
MINIMUM WATER REQUIRED
FOR 5% RESIDUAL
FALLOUT SIZE B PARTICLES
Mass Median Diameter - 112 μ
Data obtained under controlled
Laboratory Conditions
(1:4)
0.25
(1:6)
0.167
(1:8)
0.125
(1:12)
0.08
(1:24)
0.04
SLOPE
ROLL
ROOFING
PLASTIC
0
1
2
3
4
5
6
7
GALLONS / MINUTE PER FT OF WIDTH

Fig. 21

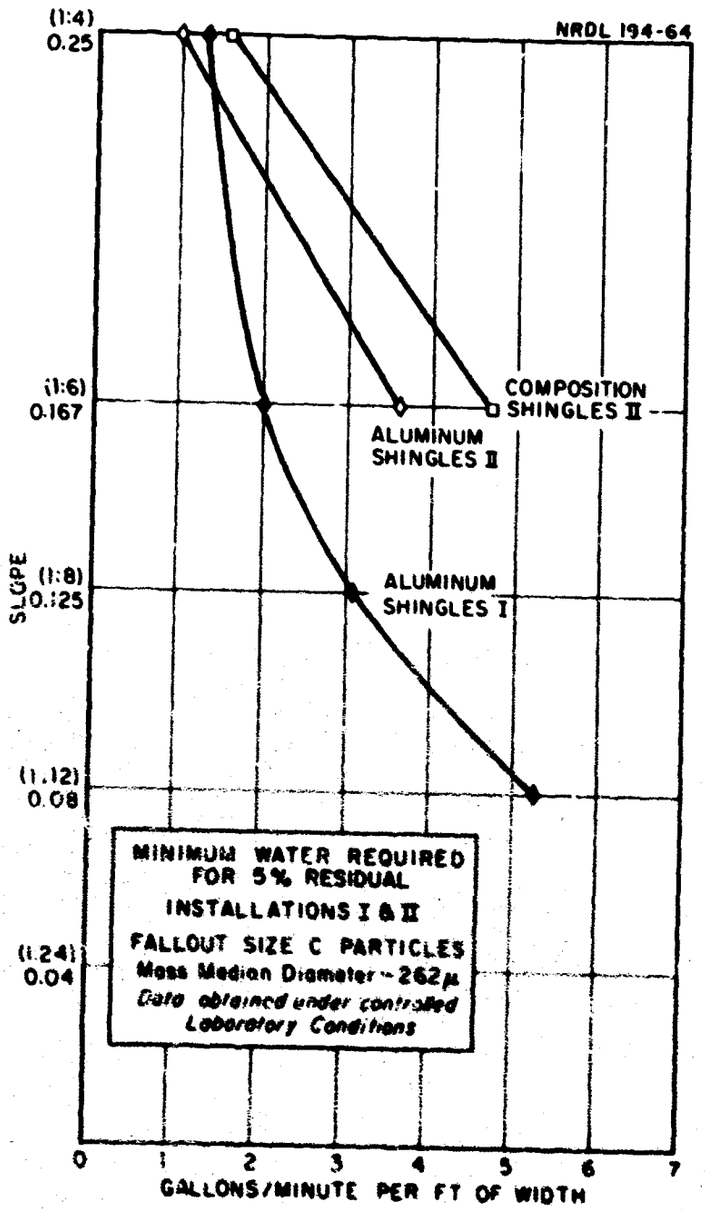
NRDL 194-64
(1:4)
0.25
(1:6)
0.167
(1:8)
0.125
(1:12)
0.08
(1:24)
0.04
SLOPE
COMPOSITION SHINGLES II
ALUMINUM SHINGLES II
ALUMINUM SHINGLES I
MINIMUM WATER REQUIRED FOR 5% RESIDUAL
INSTALLATIONS I & II
FALLOUT SIZE C PARTICLES
Mass Median Diameter ~ 262 μ
Data obtained under controlled Laboratory Conditions
0
1
2
3
4
5
6
7
GALLONS/MINUTE PER FT OF WIDTH

Fig. 22

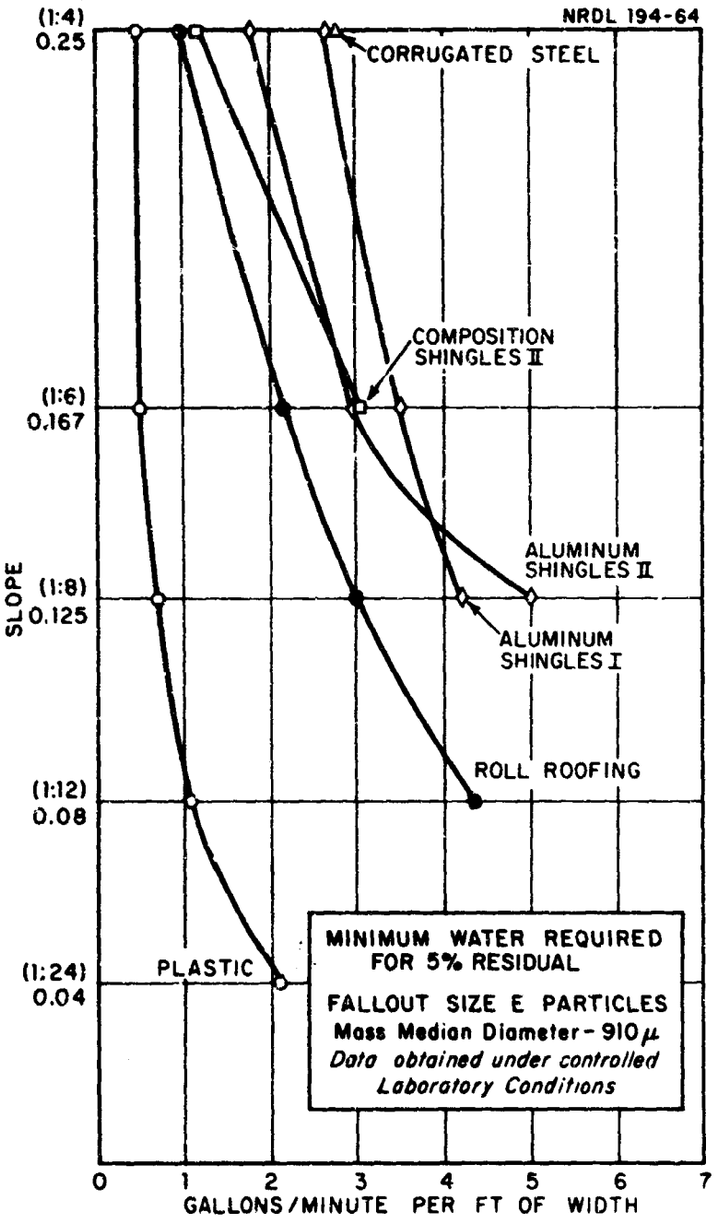
NRDL 194-64
(1:4)
0.25
(1:6)
0.167
(1:8)
0.125
(1:12)
0.08
(1:24)
0.04
SLOPE
CORRUGATED STEEL
COMPOSITION SHINGLES II
ALUMINUM SHINGLES II
ALUMINUM SHINGLES I
ROLL ROOFING
PLASTIC
MINIMUM WATER REQUIRED FOR 5% RESIDUAL
FALLOUT SIZE E PARTICLES
Mass Median Diameter - 910 μ
Data obtained under controlled Laboratory Conditions
0
1
2
3
4
5
6
7
GALLONS/MINUTE PER FT OF WIDTH

Fig. 23

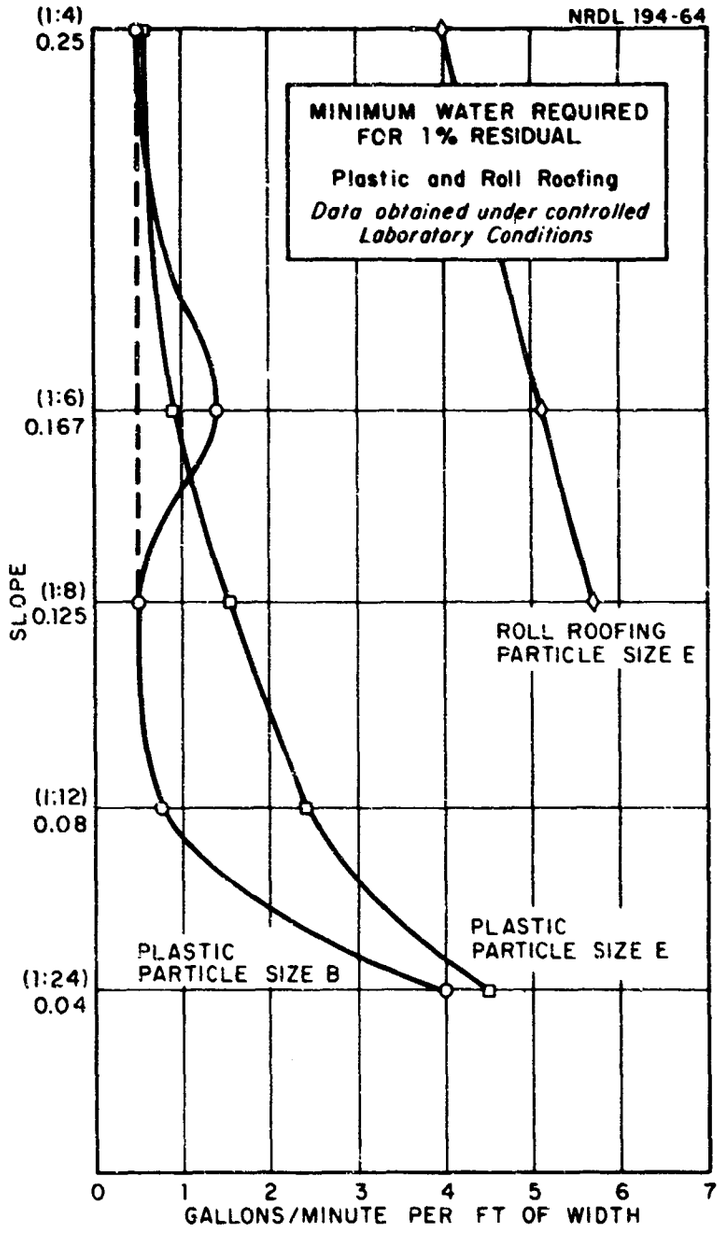
NRDL 194-64
MINIMUM WATER REQUIRED FOR 1% RESIDUAL
Plastic and Roll Roofing
Data obtained under controlled Laboratory Conditions
(1:4) 0.25
(1:6) 0.167
(1:8) 0.125
(1:12) 0.08
(1:24) 0.04
SLOPE
ROLL ROOFING PARTICLE SIZE E
PLASTIC PARTICLE SIZE E
PLASTIC PARTICLE SIZE B
0 1 2 3 4 5 6 7
GALLONS/MINUTE PER FT OF WIDTH

Fig. 24

REFERENCES

1. R. H. Heiskell, W. S. Kehrer, N. J. Vella, G. Brown, LCDR USN (Ret). 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), U. S. Naval Radiological Defense Laboratory Technical Report, USNRDL-TR-672, July 18, 1963.

2. 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, December 13, 1962.

APPENDIX A

SIEVE ANALYSES

Particle Size E
590-1190 μ

U. S. Sieve No.	μ	%	% Cumulative Wt.
16	1190	5.85	5.85
18	1000	15.98	21.83
20	890	41.28	63.11
25	710	18.43	81.54
30	590	6.60	88.14
35	500	3.83	91.97
40	420	2.32	94.29
45	350	1.88	96.17
Pan	0	3.77	99.9

Mass Median Diameter 910 μ

Particle Size D
350-590 μ

U. S. Sieve No.	μ	%	% Cumulative Wt.
25	710	0.2	0.2
30	590	1.1	1.3
35	500	13.8	15.1
40	420	39.4	54.5
45	350	39.4	93.4
Pan	0	5.6	99.5

Mass Median Diameter 450 μ

Particle Size C
177-350 μ

U. S. Sieve No.	μ	%	% Cumulative Wt.
45	350	2.0	2.0
50	297	12.5	14.5
80	177	81.1	95.6
100	147	2.8	98.4
200	74	1.3	99.7
Pan	0	0.2	99.9

Mass Median Diameter 262 μ

Particle Size B
88-177 μ

U. S. Sieve No.	μ	%	% Cumulative Wt.
70	208	1.1	1.1
80	174	2.6	3.7
120	124	30.0	33.7
140	104	42.2	75.9
170	88	13.9	89.8
230	61	9.6	99.4
Pan	0	0.5	99.5

Mass Median Diameter 112 μ

Particle Size A
44-88 μ

U. S. Sieve No.	μ	%	% Cumulative Wt
140	104	0.1	0.1
170	88	4.2	4.3
200	74	6.6	10.9
230	61	50.8	61.7
270	53	10.1	71.8
325	44	21.3	93.1
Pan	0	7.0	100.0

Mass Median Diameter 63 μ

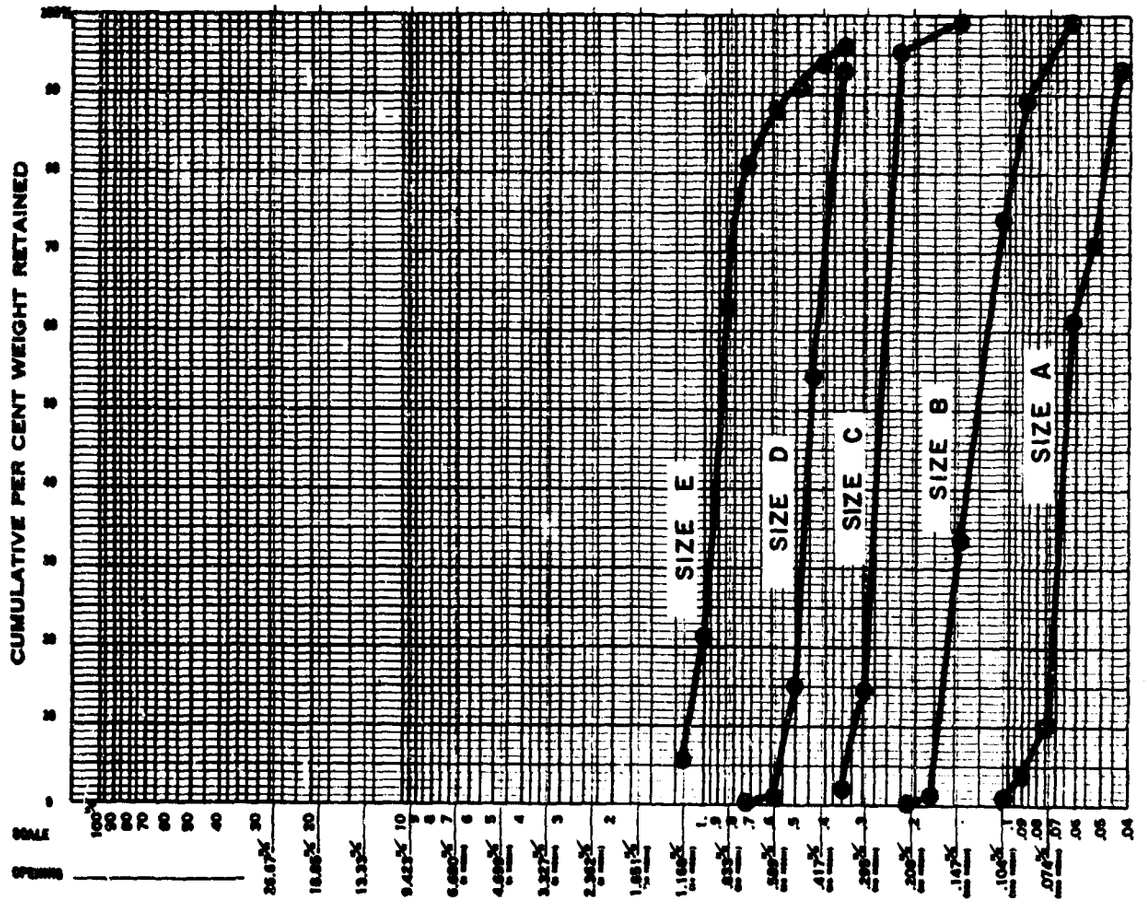

Fig. A.1 Screen Analyses of Simulated Particle Sizes

APPENDIX B

TABULATED DATA ON WASHDOWN EFFECTIVENESS FOR ROOFING SURFACES

TABLE B.1

Surface - Aluminum Shingle, Installation II
Particle Size - 88-177 μ
Surface Dimension - 8 ft wide by 48 ft long
Fallout Deposition - 2 grams/min/sq ft for 30 min
Washdown Period - During fallout period plus 30 min after fallout period

Run No.	Water Flow gal/min/ft	Fallout Deposited		Residual	
		Total Grams	Gm/min/ft^2	Grams	Percent
			Slope 1:8*		
A-58	1.0	22,365	1.94	16,321	73.0
A-28	3.0	21,096	1.83	7,808	37.0
A-59	5.3	27,257	2.37	4,032	14.8
A-56	5.3	18,358	1.59	1,856	10.1
A-40	5.45	25,057	2.17	3,099	12.4
			Ave. 1.98		
			Slope 1:6		
A-43	1.0	20,507	1.78	12,629	61.6
A-42	3.0	25,895	2.25	2,556	9.9
A-41	5.5	20,417	1.77	1,130	5.5
			Ave. 1.93		
			Slope 1:4		
A-31	1.0	20,665	1.79	1,492	7.2
A-29	3.0	20,417	1.77	564	2.8
A-30	5.3	21,005	1.87	405	1.9
			Ave. 1.79		

*No runs made at slope of less than 1:8.

TABLE B.2

Surface - Composition Shingle - Installation II
Particle Size - 88-177 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	Fallout Deposited		Residual	
		Total Grams	Gm/min/ft^2	Grams	Percent
		Slope 1:8			
A-58	1.0	23,836	2.07	8,262	34.7
A-28	1.0	23,628	2.05	7,556	32.0
A-27	3.0	20,074	1.74	2,712	13.5
A-56	5.0	19,377	1.68	1,947	10.0
A-59	5.0	24,387	2.12	2,407	9.9
A-40	5.0	25,779	2.23	2,327	9.0
		Ave.	1.98		
		Slope 1:6			
A-43	1.0	24,556	2.13	5,564	22.7
A-42	3.0	26,775	2.32	2,010	7.5
A-41	5.3	21,071	1.82	1,150	5.5
		Ave.	2.09		
		Slope 1:4			
A-29	1.0	24,485	2.12	3,252	13.3
A-30	3.0	21,388	1.85	1,286	6.0
A-31	4.9	20,776	1.80	1,127	5.4
		Ave.	1.92		

No runs made with slope of less than 1:8

TABLE B.3

Surface - Fiberglass
Particle Size - 88-177 μ
Surface Dimensions - 8 ft wide by 48 ft long
Fallout Deposition: 2 grams/min/sq ft for 30 min
Washdown Period: During fallout and for 30 min after fallout period

Run No.	Water Flow gal/min/ft	Fallout Deposited		Residual	
		Total Grams	Gm/min/ft^2	Grams	Percent
		Slope 1:24			
C-73	0.5	22,788	1.98	4,724	20.7
C-74	1.0	21,725	1.89	2,257	10.4
C-71	2.0	24,668	2.14	2,144	8.7
C-101	4.0	19,133	1.66	186	1.0
		Ave.	1.92		
		Slope 1:12			
C-78	0.5	28,832	2.50	1,917	6.6
C-79	1.0	22,901	1.99	151	0.7
C-75	2.0	21,906	1.90	84	0.4
C-76	4.0	24,317	2.11	73	0.3
		Ave.	2.13		
		Slope 1:8			
C-46	0.5	24,674	2.14	249	1.0
C-44	1.0	23,044	2.00	113	0.5
C-55	1.0	21,460	1.86	68	0.3
C-57	1.0	18,381	1.60	45	0.2
C-89	1.0	18,856	1.64	45	0.2
C-56	2.0	17,929	1.56	91	0.5
C-43	2.0	24,969	2.17	68	0.3
C-53	4.0	20,894	1.81	91	0.4
C-84	4.0	22,008	1.91	73	0.3
C-47	4.0	28,409	2.47	45	0.2
		Ave.	1.92		
		Slope 1:6			
C-59	0.5	21,091	1.83	265	1.3
C-58	2.0	20,273	1.76	171	0.8
C-60	4.0	19,118	1.66	80	0.4
Continued		Ave.	1.75		

TABLE B.3 (cont'd)

Run No.	Water Flow gal/min/ft	Fallout Deposited		Residual	
		Total Grams	Gm/min/ft^2	Grams	Percent
		Slope 1:4			
C-49	0.5	25,693	2.23	136	0.5
C-50	1.0	14,850	1.29	45	0.3
C-51	2.0	20,056	1.74	90	0.4
C-81	2.0	19,303	1.68	84	0.4
C-82	2.0	18,635	1.62	61	0.3
C-61	4.0	18,971	1.63	46	0.2
C-52	4.0	19,446	1.69	46	0.2
			Ave. 1.70		

TABLE B.4

Surface - Roll Roofing
Particle Size - 88-177 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	Fallout Deposited		Residual	
		Total Grams	Gm/min/ft^2	Grams	Percent
		Slope 1:24			
C-101	1.0	23,193	2.01	12,191	52.6
C-71	2.0	25,344	2.20	12,441	49.1
C-74	4.0	21,996	1.91	5,265	23.9
C-72	5.5	28,473	2.47	4,342	15.2
		Ave.	2.15		
		Slope 1:12			
C-78	1.0	31,048	2.69	7,506	24.2
C-75	2.0	22,400	1.94	3,657	16.3
C-77	4.0	26,118	2.27	3,436	13.2
C-79	4.0	23,352	2.03	2,028	8.7
C-76	5.5	25,575	2.21	1,512	5.9
		Ave.	2.23		
		Slope 1:8			
C-89	1.0	20,712	1.80	3,599	17.3
C-44	1.0	26,553	2.30	4,165	15.7
C-55	1.0	24,539	2.13	3,690	15.0
C-57	1.0	22,491	1.95	3,363	15.0
C-56	2.0	21,822	1.89	2,535	11.6
C-45	2.0	31,329	2.72	2,467	7.9
C-53	4.0	24,788	2.15	838	3.4
C-46	5.5	28,567	2.48	611	2.1
C-90	5.5	20,713	1.80	385	1.9
		Ave.	2.14		

Continued

TABLE B.4 (Cont'd)

Run No.	Water Flow gal/min/ft	Fallout Deposited		Residual	
		Total Grams	Gm/min/ft^2	Grams	Percent
		Slope 1:6			
C-59	1.0	25,400	2.20	2,865	11.3
C-58	2.0	24,361	2.11	1,927	7.9
C-83	2.0	25,547	2.22	1,167	4.6
C-80	4.0	21,840	1.90	425	1.9
C-60	5.5	23,399	2.03	286	1.2
			Ave. 2.09		
		Slope 1:4			
C-49	1.0	29,019	2.52	1,380	4.8
C-50	2.0	17,384	1.51	452	2.6
C-81	4.0	20,862	1.81	330	1.6
C-82	4.0	20,216	1.75	194	1.0
C-61	5.5	23,522	2.04	365	1.6
C-52	5.5	23,387	2.03	320	1.4
			Ave. 1.94		

TABLE B.5

Surface - Corrugated Galvanized Steel
Particle Size - 88-177 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	Fallout Deposited		Residual	
		Total Grams	Gm/min/ft^2	Grams	Percent
		Slope 1:8			
C-57	1.0	20,653	1.79	12,775	61.9
C-55	1.0	22,215	1.93	13,590	61.2
C-89	1.0	17,997	1.56	10,300	57.2
C-56	2.0	20,110	1.75	11,123	55.3
C-54	2.0	25,113	2.18	13,681	54.5
C-53	2.0	22,633	1.96	11,258	49.7
C-90	3.0	17,521	1.52	8,127	46.4
C-47	3.4	28,614	2.48	12,292	43.0
C-84	5.0	21,415	1.86	8,557	40.0
C-48	7.0	21,391	1.86	6,496	30.0
C-45	7.0	27,866	2.42	6,995	25.1
		Ave.	1.85		
		Slope 1:6			
C-60	1.0	20,856	1.81	12,096	58.0
C-80	1.4	21,215	1.84	11,092	52.3
C-58	2.0	22,521	1.95	11,700	52.0
C-83	5.0	22,818	1.98	8,647	37.9
C-59	7.0	23,180	2.01	6,700	28.9
		Ave.	1.92		
		Slope 1:4			
C-52	0.8	21,649	1.88	10,715	49.5
C-81	1.4	19,490	1.69	9,100	46.7
C-51	1.9	22,049	1.91	8,444	38.3
C-50	3.0	16,388	1.42	6,202	37.8
C-82	5.0	19,117	1.66	6,225	32.6
C-49	7.0	26,372	2.29	6,316	23.9
		Ave.	1.81		

No runs made with slope of less than 1:8.

TABLE B.6

Surface - Aluminum Shingle, Installation I
Particle size - 177-350 μ
Surface Dimensions - 7.5 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	Fallout Deposited		Residual	
		Total Grams	gm/min/ft^2	Grams	Percent
The following results were extracted from Table B.2, Ref. 2.					
		Slope 1:8			
119	1.95	26,243	2.43	1,989	7.6
117	3.0	27,616	2.56	1,262	4.6
116	4.0	24,265	2.25	838	3.5
111	5.1	23,896	2.21	536	2.2
			Ave. 2.38		
		Slope 1:6			
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
23[illegible]	5.0	22,433	2.08	369	1.6
			Ave. 2.10		
		Slope 1:4			
126	1.0	20,075	1.86	1,195	6.0
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
121	5.5	22,388	2.07	391	1.7
			Ave. 1.92		

TABLE B.7

Surface - Aluminum Shingles, Installation II
Particle size - 177-350 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	Fallout Deposited		Residual	
		Total Grams	gm/min/ft^2	Grams	Percent
		Slope 1:8			
A-23	1.0	28,126	2.44	17,916	63.7
A-21-A	3.0	27,641	2.34	4,571	16.5
A-22	5.3	31,430	2.73	1,945	6.2
			Ave. 2.50		
		Slope 1:6			
A-24	1.0	17,794	1.55	7,002	39.4
A-25	5.3	23,101	2.01	500	2.2
			Ave. 1.78		
		Slope 1:4			
A-17	1.0	38,475	3.34	1,418	3.7
A-18	2.0	35,337	3.11	514	1.5
A-19	4.0	29,896	2.59	168	0.6
A-20	5.3	28,119	2.47	156	0.6
			Ave. 2.88		

No runs made with slope of less than 1:8.

TABLE B.8

Surface - Composition Shingle, Installation I
Particle Size - 177-350 μ
Surface Dimensions - 8 ft wide by 48 ft long
Fallout Period - 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	Fallout Deposited		Residual	
		Total Grams	gm/min/ft^2	Grams	Percent
The following results were extracted from Table B.3, Ref. 1.					
		Slope 1:8			
230	1.0	20,969	1.80	4,312	20.6
115	1.95	24,310	2.11	2,670	11.0
117	3.5	25,975	2.25	2,514	9.7
118	4.5	25,840	2.24	2,491	9.6
			Ave. 2.10		
		Slope 1:6			
128	1.0	20,266	1.76	2,927	14.4
232	2.0	20,423	1.77	2,190	10.7
131	3.5	21,461	1.86	1,933	9.0
132	4.5	21,930	1.90	1,821	8.3
			Ave. 1.82		
		Slope 1:4			
125	1.0	21,025	1.82	2,726	13.0
234	2.0	22,980	1.99	2,033	8.8
122	3.5	22,523	1.95	1,553	6.9
121	4.5	21,763	1.89	1,553	7.1
			Ave. 1.91		

TABLE B.9

Surface - Composition Shingles, Installation II
Particle Size - 177-350 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

			Slope 1:8		
A-21-A	1.0	26,820	2.33	3,537	13.2
A-22	3.0	31,326	2.72	2,146	6.9
A-23	5.0	27,298	2.37	1,455	5.3
			Ave. 2.47		
			Slope 1:6		
A-25	1.0	20,864	1.81	2,307	11.1
A-24	5.3	17,814	1.55	833	4.7
			Ave. 1.68		
			Slope 1:4		
A-20	1.0	24,154	2.13	1,732	7.2
A-18	2.0	34,655	3.05	1,575	4.5
A-19	4.0	28,343	2.46	1,117	3.9
			Ave. 2.55		

TABLE B.10

Surface - Aluminum Shingles, Installation I
Particle Size - 590-1190 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	Fallout		Residual	
		Total Grams	gm/min/ft^2	Grams	Percent
		Slope 1:8			
366	1.0	23,690	2.06	8,523	36.0
365	2.0	21,811	1.89	4,086	18.7
364	4.0	19,751	1.71	1,075	5.4
363	5.6	17,420	1.51	453	2.6
		Ave.	1.79		
		Slope 1:6			
359	1.0	19,366	1.68	5,263	27.2
360	2.0	24,743	2.15	4,856	19.6
361	4.0	23,611	2.05	781	3.3
362	5.6	24,404	2.12	306	1.3
		Ave.	2.00		
		Slope 1:4			
358	1.0	21,652	1.88	4,380	20.2
357	2.0	23,441	2.03	2,071	8.8
356A	4.0	23,928	2.08	566	2.4
356B	4.0	21,267	1.85	350	1.6
356	4.0	29,010	2.52	396	1.4
355	5.5	19,977	1.73	147	0.7
		Ave.	2.01		

No runs made with slope of less than 1:8.

TABLE B.11

Surface - Aluminum Shingles, Installation II
Particle Size 590 - 1190 μ
Surface Dimensions - 8 ft wide by 48 ft long
Fallout Deposition - 2 gms/min/sq ft for 30 min
Washdown Period - During fallout plus 30 min after fallout period

Run No.	Water Flow gal/min/ft	Fallout Deposited		Residual	
		Total Grams	gm/min/ft^2	Grams	Percent
		Slope 1:8			
A-10	1.0	24,639	2.14	15,878	64.4
A-11	2.0	27,984	2.43	7,369	26.4
A-12	4.0	23,599	2.05	1,958	8.3
A-13	5.3	27,836	2.42	1,166	4.2
			Ave. 2.26		
		Slope 1:6			
A-9	1.0	24,041	2.09	7,436	30.9
A-8	2.0	26,157	2.27	2,705	10.3
A-7	4.0	23,999	2.08	656	2.7
A-6	5.0	25,796	2.24	453	1.8
			Ave. 2.17		
		Slope 1:4			
A-4	1.0	23,701	2.06	2,003	8.5
A-3	2.0	21,574	1.87	985	4.6
A-2	4.0	18,754	1.62	237	1.3
A-5	4.0	23,102	2.01	215	0.9
A-1	5.3	20,826	1.81	181	0.9
A-14	5.3	22,445	1.95	102	0.5
			Ave. 1.89		

No runs made with slope of less than 1:8.

TABLE B.12

Surface - Composition Shingle, Installation I
Particle Size - 590-1190 μ
Surface Dimensions - 8 ft wide by 48 ft long
Deposition Rate - 2 grams/min/sq ft for 30 min
Washdown Period - During fallout plus 30 min after fallout

Run No.	Water Flow gal/min/ft	Fallout Deposited		Residual	
		Total Grams	gm/min/ft^2	Grams	Percent
		Slope 1:8			
366	1.0	24,007	2.08	13,322	55.5
365	2.0	21,019	1.82	3,090	14.7
364	4.0	19,276	1.67	2,366	12.3
363	5.0	16,662	1.45	2,366	14.2
		Ave.	1.75		
		Slope 1:6			
359	1.0	19,140	1.66	7,482	39.1
360	2.0	24,743	2.15	4,856	19.6
361	4.0	23,214	2.01	2,818	12.1
362	5.0	24,030	2.09	3,022	12.6
		Ave.	1.98		
		Slope 1:4			
358	1.0	18,473	1.60	3,747	20.3
357	2.0	23,237	2.02	3,362	14.8
356A	4.0	25,409	2.21	3,271	12.8
356B	4.0	18,556	1.61	1,913	10.3
355	4.5	19,603	1.70	1,301	6.6
		Ave.	1.83		

No runs made with slope of less than 1:8.

TABLE B.13

Surface - Composition Shingle, Installation II
Particle Size - 590-1190 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

Run No.	Water Flow gal/min/ft	Fallout Deposited		Residual	
		Total Grams	gm/min/ft^2	Grams	Percent
		Slope 1:8			
A-10	1.0	23,962	2.08	6,271	26.2
A-11	2.0	26,712	2.32	2,886	10.8
A-16	3.0	22,898	1.99	1,743	7.6
A-12	4.0	22,027	1.91	1,619	7.4
A-13	4.8	25,739	2.23	1,687	6.6
		Ave.	2.11		
		Slope 1:6			
A-9	1.0	23,034	2.00	5,422	23.5
A-8	2.0	24,754	2.15	1,834	7.4
A-7	4.0	22,276	1.93	804	3.6
A-6	5.0	25,082	2.18	939	3.7
		Ave.	2.06		
		Slope 1:4			
A-4	1.0	22,648	1.97	3,248	14.3
A-3	2.0	19,479	1.69	486	2.5
A-5	4.0	22,525	1.96	555	2.5
A-2	4.0	18,314	1.59	283	1.5
A-1	4.5	19,909	1.73	407	2.0
A-14	4.6	22,456	1.95	441	2.0
		Ave.	1.82		

No runs made at slope of less than 1:8.

TABLE B.14

Surface - Fiberglass
Particle Size - 590-1190 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	Fallout Deposited		Residual	
		Total Grams	gm/min/ft^2	Grams	Percent
		Slope 1:24			
C-21	0.5	23,249	2.02	1' 228	61.2
C-22	1.0	21,211	1.84	4,267	20.1
C-23	2.0	24,131	2.09	1,7[illegible]4	7.3
C-24	4.0	26,056	2.26	328	1.3
		Ave.	2.05		
		Slope 1:12			
C-20	0.5	23,340	2.03	5,309	22.7
C-19	1.0	21,517	1.87	1,132	5.3
C-18	2.0	23,045	2.00	306	1.3
C-17	4.0	20,391	1.80	125	0.6
		Ave.	1.92		
		Slope 1:8			
C-13	0.5	21,200	1.84	2,671	12.3
C-14	2.0	15,812	1.37	113	0.7
C-10	4.0	19,468	1.69	79	0.4
		Ave.	1.63		
		Slope 1:6			
C-8	0.5	19,038	1.65	1,098	5.8
C-6	1.0	18,042	1.57	170	0.9
C-7	[illegible].0	20,351	1.77	102	0.5
C-9	4.0	22,298	1.94	102	0.5
		Ave.	1.73		

Continued

TABLE B.14 (Cont'd)

Run No.	Water Flow gal/min/ft	Fallout Deposited		Residual	
		Total Grams	gm/min/ft^2	Grams	Percent
		Slope 1:4			
C-4	0.5	24,969	2.17	283	1.1
C-5	1.0	21,619	1.88	102	0.5
C-2	2.0	29,610	2.57	125	0.4
C-1	4.0	23,848	2.07	45	0.2
			Ave. 2.17		

TABLE B.15

Surface - Roll Roofing
Particle Size - 590-1190 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	Fallout Deposited		Residual	
		Total Grams	gm/min/ft^2	Grams	Percent
		Slope 1:24			
C-21	1.0	24,493	2.12	23,621	96.4
C-22	2.0	22,411	1.95	17,057	76.1
C-23	4.0	25,421	2.21	6,485	25.5
C-24	5.5	27,640	2.40	2,999	10.8
			Ave. 2.17		
		Slope 1:12			
C-20	1.0	24,607	2.14	8,931	36.3
C-19	2.0	23,883	2.07	2,728	11.4
C-18	4.0	25,105	2.18	1,505	6.0
C-17	5.5	21,981	1.91	600	2.7
			Ave. 2.07		
		Slope 1:8			
C-13	1.0	24,075	2.09	3,407	14.2
C-12	2.0	24,894	2.16	1,551	6.2
C-14	4.0	17,567	1.52	532	3.0
C-16	4.0	25,953	2.25	758	2.9
C-10	5.5	21,075	1.83	226	1.1
			Ave. 1.97		
		Slope 1:6			
C-7	1.0	21,302	1.85	1,743	8.2
C-6	2.0	18,642	1.62	1,007	5.4
C-8	4.0	21,596	1.87	294	1.4
C-9	5.5	23,984	2.08	192	0.8
Continued			Ave. 1.85		

TABLE B.15 (cont'd)

Run No.	Water Flow gal/min/ft	Fallout Deposited		Residual	
		Total Grams	gm/min/ft^2	Grams	Percent
		Slope 1:4			
C-25	1.0	25,274	2.19	1,256	5.0
C-3	2.0	22,751	1.97	634	2.8
C-4	2.0	26,146	2.27	611	2.3
C-2	2.0	30,277	2.63	690	2.3
C-5	2.0	23,045	2.00	521	2.3
C-33	4.0	25,048	2.17	260	1.0
C-1	4.0	24,460	2.12	136	0.6
C-21	5.5	21,562	1.87	170	0.8
C-26	5.5	24,312	2.11	147	0.6
			Ave. 2.15		

TABLE B.16

Surface - Corrugated Galvanized Steel
Particle Size - 590-1190 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	Fallout Deposited		Residual	
		Total Grams	gm/min/ft^2	Grams	Percent
		Slope 1:8			
C-37	1.0	24,913	2.16	4,924	19.8
C-13	1.0	21,630	1.88	3,690	17.1
C-38	2.0	24,857	2.16	3,328	13.4
C-14	2.0	16,186	1.40	1,687	10.4
C-29	2.0	24,754	2.15	2,388	9.6
C-39	4.0	24,619	2.09	2,015	8.2
C-16	4.0	25,285	2.19	1,731	6.8
C-40	7.0	20,770	1.80	1,347	6.5
C-10	7.0	19,966	1.73	1,098	5.5
			Ave. 1.95		
		Slope 1:6			
C-6	1.0	17,046	1.48	2,320	13.6
C-7	2.0	20,690	1.80	1,754	8.5
C-8	4.0	19,921	1.73	1,302	6.5
C-34	7.0	27,027	2.35	1,437	5.3
C-9	7.0	23,147	2.01	1,177	5.1
C-32	7.0	27,120	2.25	1,143	4.2
			Ave. 1.94		
		Slope 1:4			
C-4	1.0	24,448	2.12	2,705	11.1
C-5	2.0	21,323	1.85	1,301	6.1
C-3	2.0	21,019	1.82	1,064	5.1
C-2	4.0	28,523	2.48	1,913	6.7
C-1	7.0	22,423	1.95	917	4.1
			Ave. 2.04		

No runs made at slope of less than 1:8.

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Fallout simulant particles ranging in size from 44 to 88, 88 to 177 and 590 to 1190 μ were deposited at a rate of approximately 2 grams/min/ft^2 for a period of 30 min on selected typical roof sections 48 ft long by 8 ft wide, to
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1. Washdown.
2. Roofs - Contamination.
3. Fallout.
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determine the effect of water flow rate, slope, and surface type on washdown effectiveness. A residual mass of less than 10% of tne 590 to 1190 μ particles was obtained on aluminum shingles, composition shingles, roll roofing, corrugated metal and fiberglass epoxy laminated roof with a maximum of 3.5 gallons of water per minute per foot of roof width (gpm/ft) at a slope of 1:8 or greater. Thirty-five to forty-five per cent of the 88 to 177 μ particles was retained on the corrugated metal at this same slope with a water flow of 3.5 gpm/ft of width. A residual of 5% or less was obtained on roll roofing at a slope of 1:8 or greater with a water flow of 3.5 gpm/ft of width with both the 88 to 177 and the 590 to 1190 μ particles. With the same two particle sizes, a residual of 5% or less was obtained on a fiberglass epoxy laminated roof with a maximum water flow of 1.0 gpm/ft of width at a slope of 1:12 or greater.

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