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Service

NENTC
Chester
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TECHNICAL NOTE

AGRICULTURAL ENGINEERING NO. 1

ROOF RUNOFF MANAGEMENT - GUTTER SELECTION SIZE

A method to determine the roof area that can be drained by a specified size of gutter and downspout size.

Introduction

The extent of roof area that can be served by a gutter system is controlled by either the flow capacity of the gutter (channel flow) or by the flow capacity of the header or downspout (orifice flow). The gutter's capacity may be computed by Manning's equation. The downspout capacity may be computed by the orifice equation.

The "Architectural Graphic Standards" 5th Edition was used to obtain gutter nd downspout dimensions.

The size of roofs on livestock housing structures are usually large, the installation and maintenance of gutters and downspouts are expensive. Considering these factors, it is recommended 5-inch gutter be the smallest gutter to be used. Five-inch gutters are available at most building supply houses and lumber yards, 6-inch guttering is availabe from some suppliers, and 7-inch guttering is considered a standard size, but in many regions of the country, it will require a special order to obtain it. In keeping with the intent of this guide to use standard or stock size gutters and downspouts, a 7-inch gutter is the largest considered.

The larger gutters may be more desirable because larger downspouts may be used and this reduces the number of downspouts needed and reduces the potential for frost damage and clogging.

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SYMBOLS, UNITS, AND DEFINITIONS

A_d (square inches) = cross sectional area of downspout or header.

A_g (square inches) = cross section (flow) area of gutter.

A_r (square feet) = area of the projection onto a horizontal plane of the roof surface which slopes one way.

A_{sr} (square feet/square inch) = specific roof area or the roof area that can be drained by 1 square inch of downspout area at a designated rainfall and size of gutter.

h (inches) = head on the orifice = total gutter depth minus 1/2 inch.

n = channel flow retardance in Manning's equation.

P (inches) = rainfall for which roof runoff is calculated.

Q_d (cubic feet) = flow volume in the downspout.

Q_g (cubic feet) = flow volume in the gutter.

Q_r (cubic feet) = volume of roof runoff.

q_d (cubic feet per second) = rate of flow in the downspout.

q_g (cubic feet per second) = rate of flow in the gutter.

q_r (cubic feet per second) = rate of runoff from the roof.

r (feet) = Hydraulic radius in Manning's equation.

s (feet/feet) = Hydraulic grade.

T_c (minutes) = Time of concentration. The T_c is assumed to be zero for a roof.

V_d (feet per second) = the velocity of flow in the downspout.

V_g (feet per second) = the velocity of flow in the gutter.

ASSUMPTIONS

. balanced system the volume runoff rate from the roof equals volume rate or flow in the gutter which equals the volume rate of flow in the downspout, or

$$q_r = q_g = q_d \qquad (1)$$

Due to physical constraints, the capacity of the system will be controlled by either q_g or q_d, and A_r must be adjusted to ensure q_r does not exceed the control rate.

GUTTER FLOW

Due to the surface conditions that are inherent or develop in gutters over a period of time (i.e., splice joints, surface scum, dust and dirt) the flow retardance in the gutter has been estimated to be 0.012. As recommended in "Architectural Graphic Standards," the gutter slope is set as 1/16 inch per foot or s = 0.00508 ft/ft. Thus,

$$V_g = \frac{1.486}{N} r^{2/3} s^{1/2} \qquad (2)$$

$$V_g = \frac{1.486}{0.012} r^{2/3} (0.00508)^{1/2}$$

$$V_g = 8.937\ r^{2/3} \qquad (3)$$

$$q_g = V_g \frac{Ag}{144} \qquad (4)$$

$$q_g = 8.937\ r^{2/3} \frac{Ag}{144}$$

$$q_g = 0.0621\ r^{2/3}\ Ag \qquad (5)$$

ORIFICE FLOW (Downspout Flow)

The volume of water that can flow in the downspout is determined by the size of the opening, A_d, in the bottom of the gutter and the head over this opening. This flow will be weir flow, orifice flow, or some transitional flow between these two. This will depend on the head over the opening. It has been determined orifice flow will be the type in effect when system is flowing at design capacity.

The orifice discharge constant, "C," is set as 0.65 for this type of a system.

$$V_d = C \left(2q \frac{h}{12}\right)^{1/2} \quad \text{(Note: h is in inches)} \qquad (6)$$

$$V_d = 0.65 \left(\frac{(2)(32.2)\ h}{12} \right)^{1/2}$$

$$V_d = 1.51\ (h)^{1/2} \qquad (7)$$

$$q_d = V_d\ A_d \qquad (8)$$

$$q_d = 1.51\ (h)^{1/2}\ \frac{Ad}{144}$$

$$q_d = 0.010488\ A_d\ (h)^{1/2} \qquad (9)$$

ROOF RUNOFF RATE

$$q_r = A_r P \qquad (10)$$

A_r = Area of roof in square feet
P = peak rainfall in 5 minutes in inches

$$q_r = A_r\ (\text{sq ft})\ \frac{P\ (\text{inches})}{5\ \text{min}} \times \frac{1\ \text{min}}{60\ \text{sec}} \times \frac{1\ \text{ft}}{12\ \text{inches}}$$

$$q_r = \frac{ArP}{3600} \qquad (11)$$

SAMPLE CALCULATIONS

lculate flow rate in Aluminum 5-inch Box OGEE Gutter. Refer to Figure 1 for ensions.

A_g = 10.71 sq in
r = 1.0944 in or 0.0912 ft
h = 3.0 inches

Equation (5)

$$q_g = 0.0621\ r^{2/3}\ A_g$$

$$g_g = 0.0621\ (0.0912)^{2/3}\ (10.71) = 0.135\ \text{cfs}$$

The bottom width of an Aluminum 5-inch box-ogee gutter is 3 inches. Largest standard downspout that can be installed in the gutter is a 3-inch x 4-inch rectangular downspout.

Equation (9) calculate g_d use equation (9)

$$q_d = 0.0105\ A_d\ (h)^{1/2}$$

$$A_d = 3\ \text{in} \times 4\ \text{in} = 12\ \text{sq inches}$$

Obtain h from Figure 1.

$h = 3$ inches

$q_d = 0.0105\ (12)(3)^{1/2} = 0.22$ cfs

$q_g = q_d$ Therefore, q_g, the smaller, is the control of the system and

$q_r = q_g = 0.135$ cfs

Equation (11) Substitute known values in Equation (11) and solve for A_r as a f(P).

$$q_r = \frac{ArP}{3600}$$

$$\frac{ArP}{3600} = 0.135 \text{ cfs} \quad \text{(solve for } A_r\text{)}$$

$$A_r = \frac{0.135\ (3600)}{P} = \frac{486}{P} \text{ sq ft}$$

With this mathematical relationship established, a list of A_r's can be calculated for a set of 5 minute rainfalls. These can be listed in a table, see Table 1 or plotted on a graph.

lculate flow rate in zinc coated steel 5-inch box-ogee gutter. (Refer to ure 1 for dimensions.)

$A_g = 15.59$ sq inches
$r = 1.2732$ inches $= 0.1061$ feet
$h = 4.25$ inches

Calculate rate of flow in gutter using Equation (5)

$$q_g = 0.0621\ r^{2/3}\ A_g$$

$$q_g = 0.0621\ (0.1061)^{2/3}\ (15.59) = 0.217 \text{ cfs}$$

Calculate rate of flow in downspout using Equation (9)

$$q_d = 0.0105\ A_d\ (h)^{1/2}$$

The flat bottom of a 5-inch galvanized steel gutter is 2.5 inches wide. The largest standard downspout to be used is 2 inches x 4 inches.

$A_d = 2 \times 4 = 8$ sq inches
$h = 4.25$ inches

$q_d = 0.0105\ (8)(4.25)^{1/2} = 0.173$ cfs

$q_d = q_g$ Therefore, q_d, the smaller is the control of the system and

$q_r = q_d = 0.173$ cfs

Equation (11)

$$q_r = \frac{ArP}{3600}$$

$$\frac{ArP}{3600} = 0.173 \text{ cfs} \quad \text{(solve for } A_r\text{)}$$

$$A_r = \frac{0.173\ (3600)}{P} = \frac{623}{P} \text{ sq ft}$$

Assign values to P and determine the value of A_r and develop a table of values table - and plot curve Figures 4 and 5.

In a similar manner the Table and Curves for 6" and 7" box ogee gutters can be developed.

Two graphs have been developed for use in determining the roof area that can be drained by a 5 inch, 6 inch, or 7 inch ogee box gutter.

Figure 4 is a plot of Roof Area Drained vs. Five Minute Rainfall when the system is controlled by the downspout (orifice) capacity.

Figure 5 is a plot of Roof Area Drained vs. Five Minute Rainfall when the system is controlled by the gutter (channel) capacity.

Table 1

Roof area that can be drained by a gutter system for various rainfalls. This system's capacity is controlled by gutter (channel) capacity.

5 minute Rainfall inches	Roof Area - Square Feet			
	Aluminum	Zinc Coated Steel Gutter & Size		
	5" Gutter	5 inch	6 inch	7 inch
0.25	1944	3124	4853	5848
0.30	1620	2603	4044	4873
0.35	1388	2231	3466	4177
0.40	1215	1952	3033	3655
0.45	1080	1736	2696	3249
0.50	972	1562	2426	2924
0.55	884	1420	2206	2658
0.60	810✓	1302	2022	2437
0.65	748	1202	1866	2249
0.70	694	1116	1733	2088
0.75	648	1041	1618	1949
0.80	608	976	1516	1828
0.85	572	919	1427	1720
0.90	540	868	1348	1624

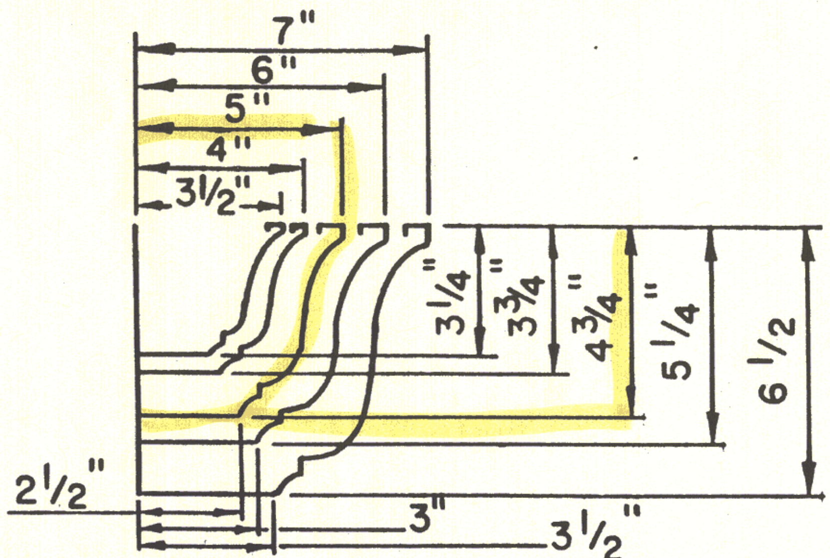
Note: For the channel flow to be the control of a roof runoff control system, a downspout cross-sectional area, A_d, must meet the following requirements.

Aluminum 5" A_d __ 7.42 square inches
Zinc-coated Steel 5" A_d __ 10.02 square inches
Zinc-coated Steel 6" A_d __ 14.73 square inches
Zinc-coated Steel 7" A_d __ 15.78 square inches.

DIMENSIONS OF LEADERS		
TYPE	AREA Sq. In.	NOM. SIZE
Plain Round	7.07	3"
	12.57	4"
	19.63	5"
	28.00	6"
Corrugated Round	5.94	3"
	11.04	4"
	17.72	5"
	25.97	6"
Polygon Octagonal	6.36	3"
	11.30	4"
	17.65	5"
	25.40	6"
Squrae Corrugated	3.80	2"
	7.73	3"
	11.70	4"
	18.75	5"
Plain Rectangular	3.94	1¾" x 2¼"
	6.00	2" x 3"
	8.00	2" x 4"
	12.00	3" x 4"
	20.00	4" x 5"
	24.00	4" x 6"

Fig. 1

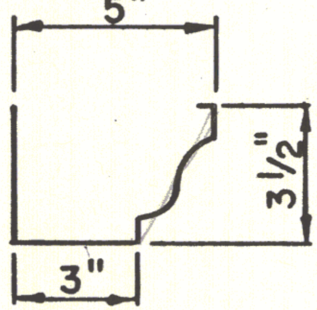
STOCK METAL GUTTERS



ZINC COATED SHEET - "ARMCO ZINCGRIP"

Armco Steel Corporation

Fig. 2



ALUMINUM

Reynolds Metals Co.

Fig. 3

FIVE MINUTE RAINFALL VS. ROOF AREA THAT CAN BE DRAINED BY 5 INCH, 6 INCH, AND 7 INCH STARDARD BOX - OGEE GUTTER - SYSTEM CAPACITY CONTROLLED BY DOWNSPOUT CAPACITY.

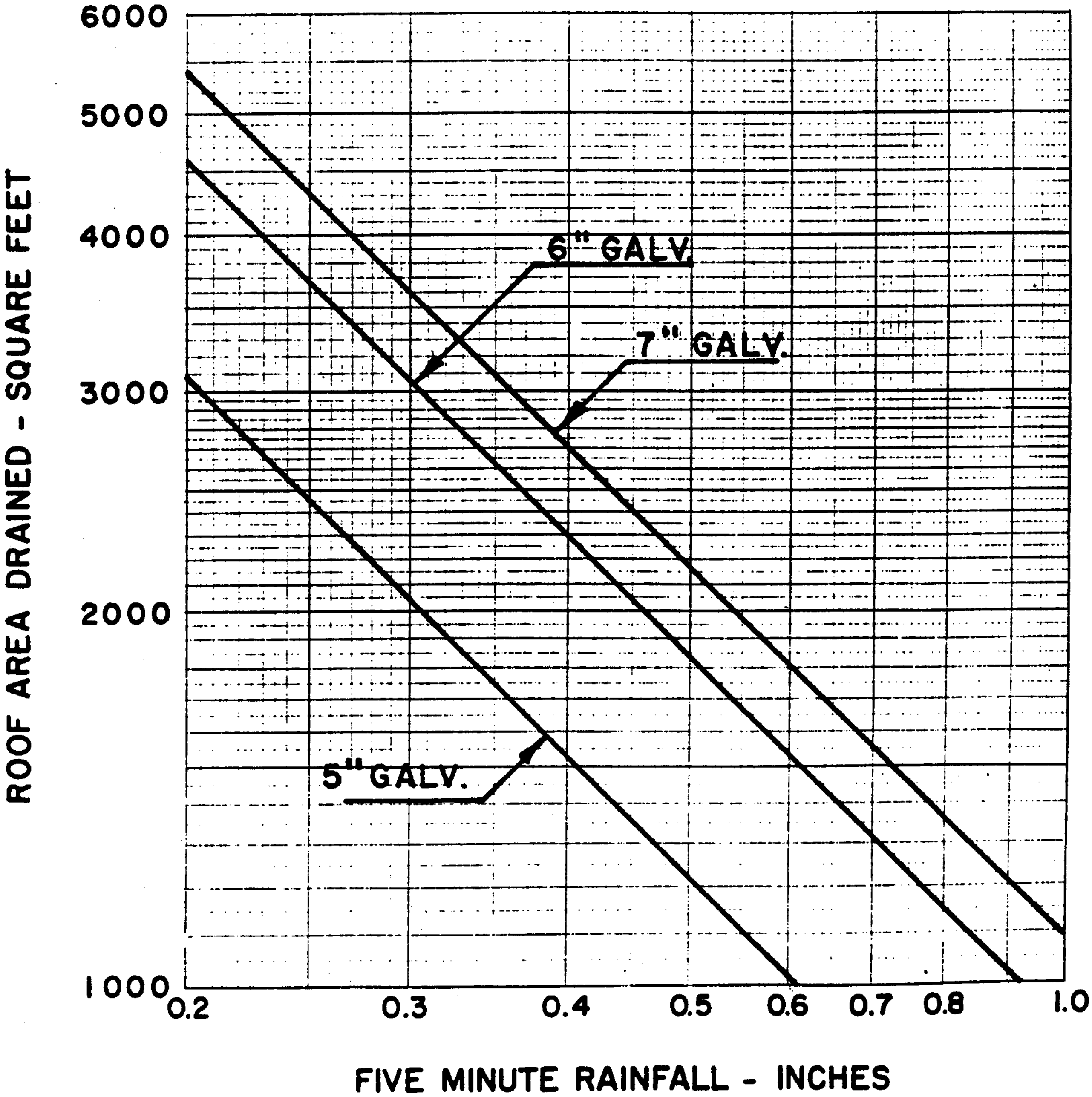


Fig. 4

FIVE MINUTE RAINFALL VS. ROOF AREA WHICH CAN BE DRAIN BY 5 INCH, 6 INCH AND 7 INCH STANDARD BOX - OGEE GUTTER - CHANNEL CAPACITY CONTROLLED SYSTEM.

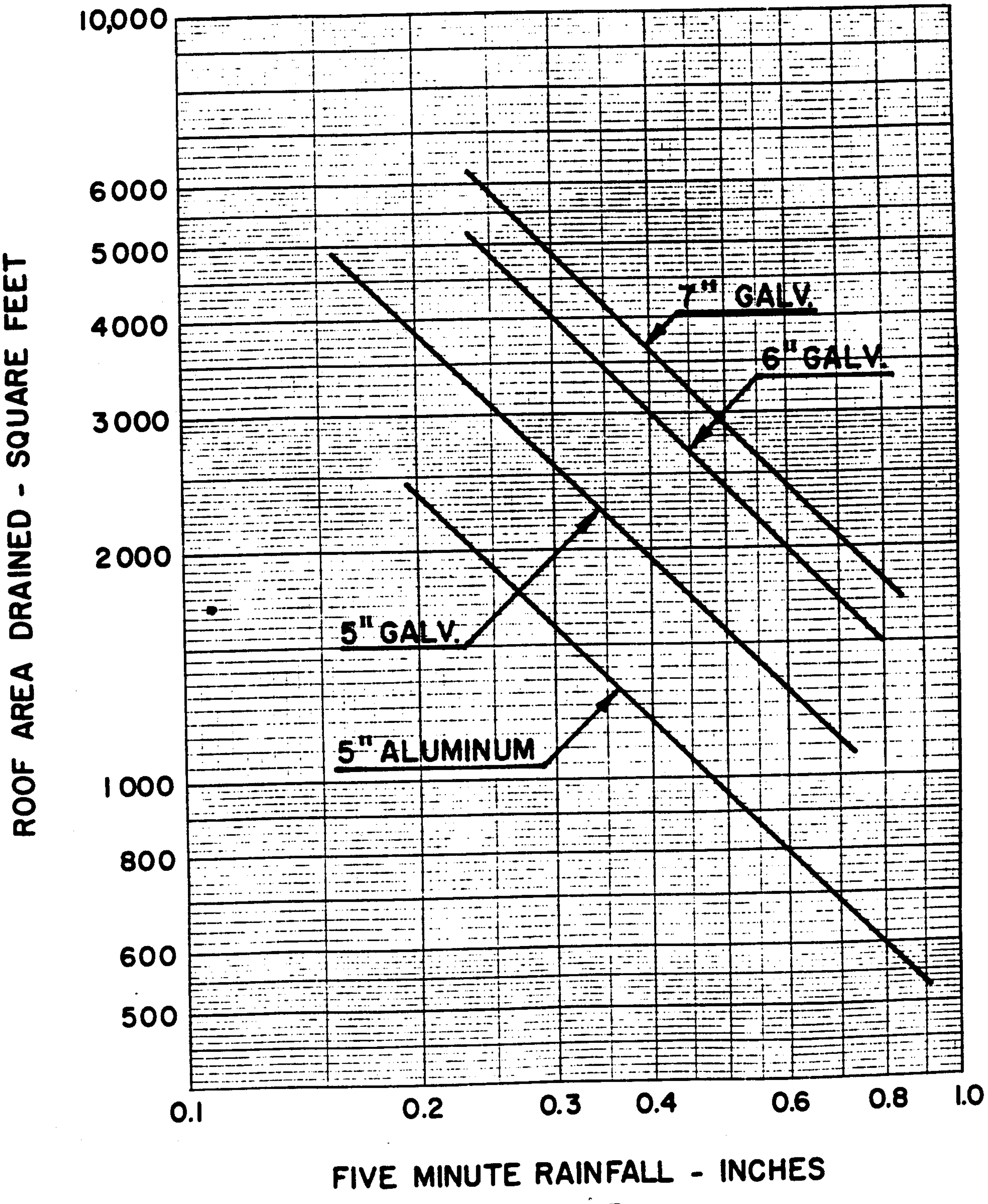


Fig. 5