The Effects of Debris on the Flow Rates of Roof Drains and Scuppers

By Jim D. Koontz, RRC, PE

Drainage of rainwater has long been considered an essential attribute for the proper performance of any roof system. Long-term and excessive accumulation of water will contribute to the deterioration of most roofing systems and, in worst-case scenarios, has been responsible for excessive live loads that can lead to structural collapse.

Roofing systems commonly rely upon roof drains and through-wall scuppers for drainage. The effects of debris on the flow rate characteristics of roof drains and scuppers has not been well understood or studied.

Routine maintenance, which should include intermittent cleaning of debris from roof surfaces, has always been recommended within the roofing industry. An August 2009 article by Eddie Garcia in *Western Roofing Magazine* discusses the importance of roof maintenance and specifically the importance of keeping a roof free of debris.[1] Numerous other authors, including Griffin and Fricklas,[2] also address the importance of roof drainage and maintenance.

The reality, however, is that roof maintenance usually occurs only after a leak or roof problem develops. The failure to routinely clean a roof can and has led to serious roof problems. Proper roof maintenance is the ultimate responsibility of the building owner.

This article reviews the effects of roof type and debris on the flow rate characteristics of roof drains and scuppers. This study was limited to debris accumulation on roof surfaces and does not consider the effects of debris within drainpipe leader systems. The data generated assume that drain leaders are clear and free to flow.

BACKGROUND

Drainage of roofing systems has typically been accomplished by a combination of slope, perimeter gutters, internal roof drains, and/or through-wall scuppers. Proper roof drainage has long been required by national building codes. Within the roofing industry, organizations such as the National Roofing Contractors Association (NRCA) and manufacturers have made longstanding recommendations and requirements for proper roof drainage.

Most roofing material manufacturers require a positive slope and that a new roof will drain and be free of ponding water within 48 hours after a rainfall event. A few single-ply and old coal-tar manufacturers have permitted accumulation of water on their roofing systems.

INTERNATIONAL BUILDING/ PLUMBING CODE

By law, roof construction has to be in compliance with locally adopted building codes. The International Building Code (IBC)[3] is currently the most uniformly accepted code within the United States. The IBC requires positive slope for new construction and incorporates the International Plumbing Code (IPC),[4] which addresses requirements for roof drainage.

The required minimum size for roof drains and/or scuppers for a given roof area is dependent upon a number of factors, including the following:

- Geographic location
- 100-year one-hour rainfall rate
- Below-deck drainpipe system (vertical or sloped)

PRIMARY DRAIN EXAMPLE

Orlando, Florida, falls within an area of the IPC, per Figure 1106.1, that indicates the maximum anticipated 100-year rainfall event could be up to 4.5 in. of rain per hour. The determination of the size of a roof drain

Properties of Water

Properties of Water
1 cubic ft. of water = 62.42 pounds
1 cubic ft. of water = 7.48 gallons
1 gallon of water = 8.34 pounds

Table A

for a given roof area is dependent on the orientation of the below-deck drain piping. Assuming horizontal leader piping at ¼ in. per ft. of slope (Table 1106.3), the maximum area of drainage for a 6-in.-diameter drain would be 6,795 sq. ft. This square footage is based upon an extrapolation between the 4- and 5-in. rainfall rate. The properties of water are included in *Table A*.

The IPC also requires the installation of independent, separate-but-equal, primary, and secondary drainage systems. The primary and secondary systems are to be equal in cross-sectional drainage capacity and have independent discharge piping or leaders. The theory is that if the primary drain/scupper becomes blocked for whatever reason, the secondary independent drain/scupper system can accommodate the anticipated rainfall event.

The flow rate for a given condition in gallons per minute (gpm) can be calculated. For the Orlando roof with 6,795 sq. ft. that experiences a 4.5-in. rainfall in one hour, the roof drain system should be capable of withstanding flow rates of up to 317 gpm during a maximum rainfall event (*Table B*).

ROOF DRAIN STRAINER

The IPC, in Section 1105.1, Strainers, also requires that roof drains have strainers with inlet openings equal to 150% of the cross-sectional area for a given drain pipe. As an example, for a 6-in. roof drain, the given cross-sectional area is approximately 28.3 sq. in. The strainer for a 6-in. roof drain would be required to have an inlet opening of at least 42.4 sq. in. The IPC does not distinguish between the vertical inlet open areas or horizontal sections on the top of the strainer. (See *Photo 1*.)

SECONDARY DRAINAGE

Under Section 1107 of the IPC, secondary roof drains are required in addition to the primary drainage system. Secondary drainage systems are required for emergency purposes in the event the primary drainage systems become blocked. The IPC requires that the secondary drainage system have separate points of discharge that are to be sized based on the same rainfall rates as that of the primary drainage system.

If scuppers are used, the size must be sufficient to prevent ponding to a depth that exceeds the design limits of the roof. The exact methodology for determining the sizing of scuppers used as the secondary drainage system is not specified under current requirements of the IPC.

DEBRIS

The type of debris found on a roof surface varies widely. Typical debris includes vegetation, leaves, trash, cans, bottles, plastic bags, dirt, etc. Field experience has shown that debris will accumulate starting at the roof surface and will extend upwards along the sides of strainers or scuppers (*Photo 2*). Debris generated by some of the new "green" roofs may also be problematic.

6,795 sq. ft. of roof X 4.5-in. rainfall/hr. = 2,548 cubic ft. of water/hr.

2,548 cubic ft. X 7.48 gallons/cubic ft. = 19,059 gallons/hr.

19,059 gallons/hr. = 317 gallons/min.

Table B

LABORATORY TESTING

In order to evaluate the effects of debris on the performance of roof drains and scuppers, an elevated steel tank was constructed and connected to pumps and a water reservoir. Different types of drain devices were flooded at incremental flow rates of 200, 400, 600, and 800 gpm. As water was pumped at different flow rates, the depth of water accumulation was measured.

The 6-in. and 8-in. diameter roof drains and four through-wall scupper assemblies were tested under varying conditions.

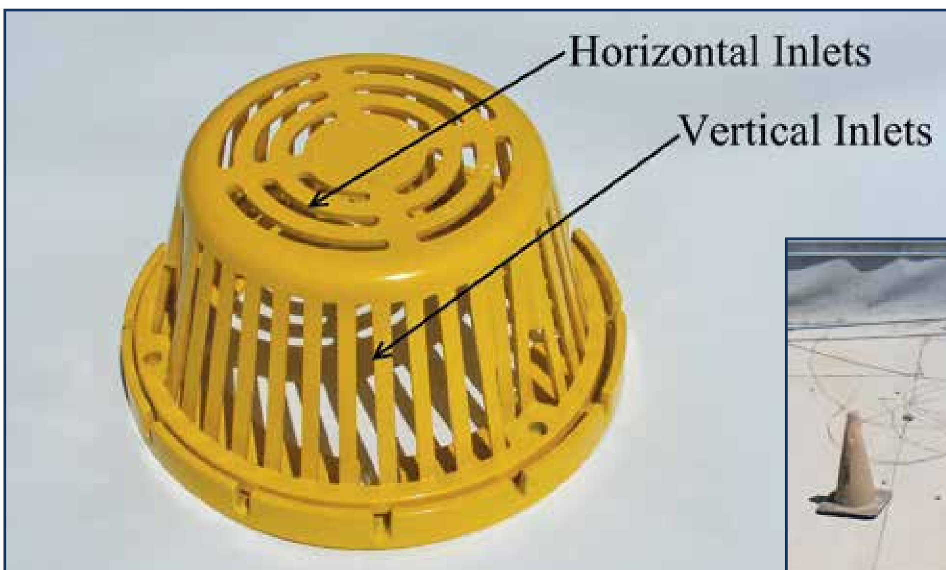


Photo 1 – Roof drain strainer.

Photo 2 – Debris at roof drain.

SIMULATED DEBRIS

Simulated debris was placed over the vertical inlets of roof strainers (*Photo 3*). The vertical inlet strainer openings were restricted at rates of 25%, 50%, and 75%. The resultant accumulation of water, depth, and flow rate were measured. Data generated from this testing are included in *Table C*.

Testing verified that a relatively small amount of debris would substantially reduce the flow rate capabilities of a primary drain assembly. As a result, water will accumulate and lead to increased structural loading.

As an example, if the 6-in. roof drain installed in Orlando without a secondary drainage system is partially obscured up to 25%, 50%, or 75%, water depth at the drain will increase from 4.4 inches to 5.4, 6.3, and 9.8 inches, respectively. As the depth of water increases, the secondary roof drainage system will engage to prevent excessive structural loading and potential collapse.

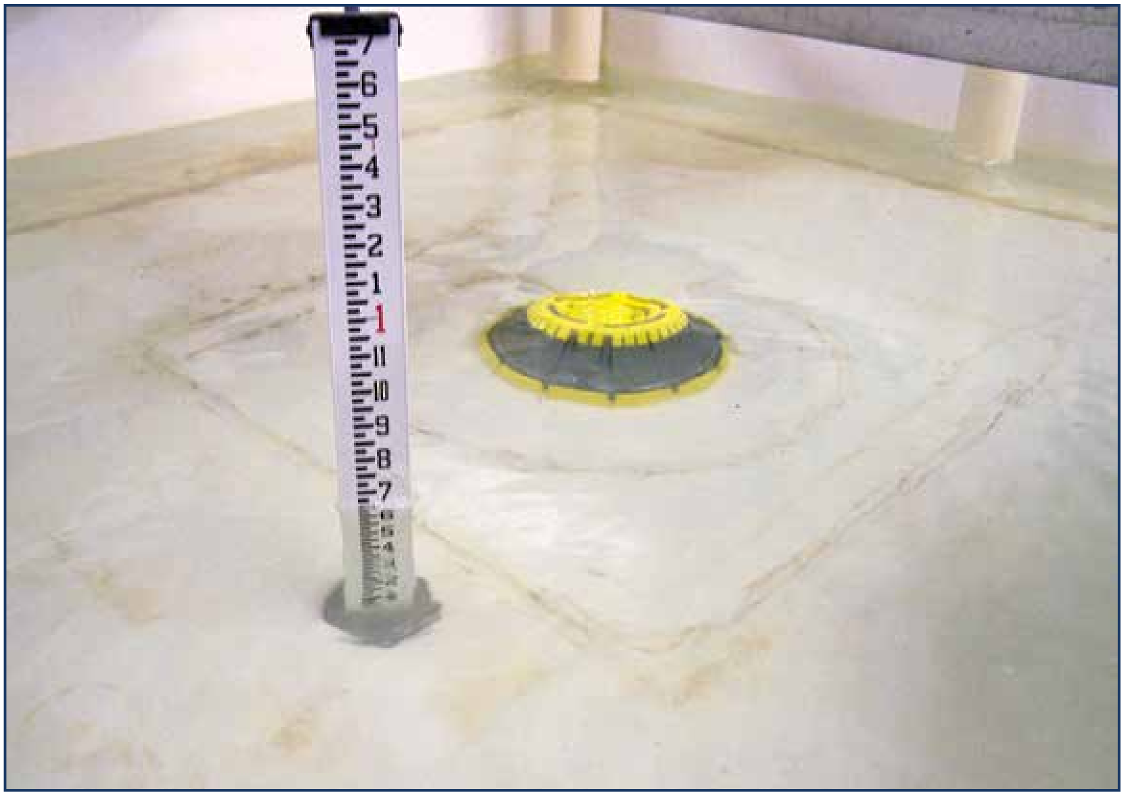


Photo 3 – Simulated debris.

RETROFIT ROOF DRAINS

Within the single-ply community, a common method of reroofing involves the use of "retrofit roof drains." The new retrofit roof drains are inserted within existing roof drains. The insert consists of a metal tube or drain stem with a horizontal flange that is welded to the single-ply membrane (*Photo 4*).

A gasket or backflow seal device placed within the vertical section of the stem expands, forcing the retrofit roof drain and the existing drainpipe to form a watertight seal. A performance standard to test this

DRAIN FLOW RESEARCH

Laboratory Roof Drain Flow Testing; Water Level, Height in Inches

8-in. Drain, 14-in. Strainer Dome, 15 ft., 6 in. of 8-in. Drain/PVC Pipe – Horizontal Configuration									
Condition – Approx. flow rate, gpm	**Open Area, in.^{2}**	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**
Without strainer	48.7	1.7	2.3	2.5	2.7	2.8	3.1	3.4	3.5
With clear strainer	97.0	2.6	2.8	3.4	3.9	4.3	4.7	5.0	5.3
Debris, 25% of side opening	78.8	3.6	3.8	4.4	4.8	5.2	5.5	6.0	6.4
Debris, 50% of side opening	60.6	4.6	4.8	5.2	5.6	6.3	6.6	6.9	7.1
Debris, 75% of side opening	42.4	5.3	5.4	6.0	6.4	6.9	7.3	7.8	7.8
6-in. Drain, 9½-in. Strainer Dome, 15 ft., 6 in. of 6-in. Drain/PVC Pipe – Horizontal Configuration									
Condition – Approx. flow rate, gpm	**Open Area, in.^{2}**	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**
Without strainer	28.3	2.6	3.3	4.4	5.9	7.5	9.5	12.0	14.8
With clear strainer	51.0	2.6	3.3	4.4	5.9	7.5	9.7	12.8	16.8
Debris, 25% of side opening	40.3	4.9	4.9	5.4	6.3	7.7	9.8	12.4	>18
Debris, 50% of side opening	29.5	5.7	6.0	6.3	7.0	9.3	13.9	>18	>18
Debris, 75% of side opening	18.7	6.4	7.5	9.8	10.3	12.0	>18	>18	>18

Table C

Photo 4 – Retrofit drain.

seal has been developed by the American National Standard Institute (ANSI) and the Single-Ply Roofing Institute (SPRI).[5]

The net result of installing a retrofit roof drain is that the cross-sectional diameter (area) of the existing drainpipe is reduced. Manufacturers have not analyzed the effect the retrofit roof drains have on the reduction of flow rates and/or increased water accumulation.

A 6-in. roof drain was retrofitted with a typical drain insert. The new assembly was then flooded with water. Data generated from the testing of the retrofit roof drains are included in *Table D*. A comparison of the 6-in. drain with and without the insert is shown in *Figure 1*.

ICE DEBRIS

Common debris that accumulates on a roof can be addressed by roof maintenance. In some instances, a hail or snow event can create an accumulation of ice at a roof drain and/or scupper. The accumulation of hail, ice, or snow, in effect, becomes meteorologically supplied debris.

During some hail events, a roof drain/scupper can rapidly become obscured, resulting in an ice dam at the drain/scupper assembly. Water accumulates, backs up, and can produce leakage at roof defects. In worst-case scenarios, water accumulation can result in roof collapse.

Testing the 6-in. roof drain, 240 pounds of ice was deposited in the testing device in order to observe this phenomenon. At 200 gpm of flow, the water level quickly rose from 3.25 in. to 6 in. In real-world situations, the amount of ice accumulation as a result of hail or snow can be significantly greater than the amounts used in testing.

DRAIN FLOW RESEARCH

Laboratory Roof Drain Flow Testing; Water Level, Height in Inches

6-In. Retrofit Drain, 9½ In. Plastic Strainer Dome, 15 Ft., 6 In. of 8-In. Drain/PVC Pipe – Horizontal Configuration

Condition – Approx. Flow Rate, gpm	Open Area, in.^{2}	100	200	300	400	500	600	700	800
Without strainer	19.6	5.2	5.3	5.8	7.3	8.2	9.8	12.7	16.0
With clear strainer	48.4	5.2	5.3	5.6	7.3	8.2	9.8	13.7	>18
Debris, 25% of side opening	35.1	5.5	5.8	5.8	6.8	7.8	10.0	14.7	>18
Debris, 50% of side opening	24.3	5.6	6.5	7.6	8.8	12.4	16.5	>18	>18
Debris, 75% of side opening	15.0	7.2	8.3	10.3	13.3	17.1	>18	>18	>1

Table D

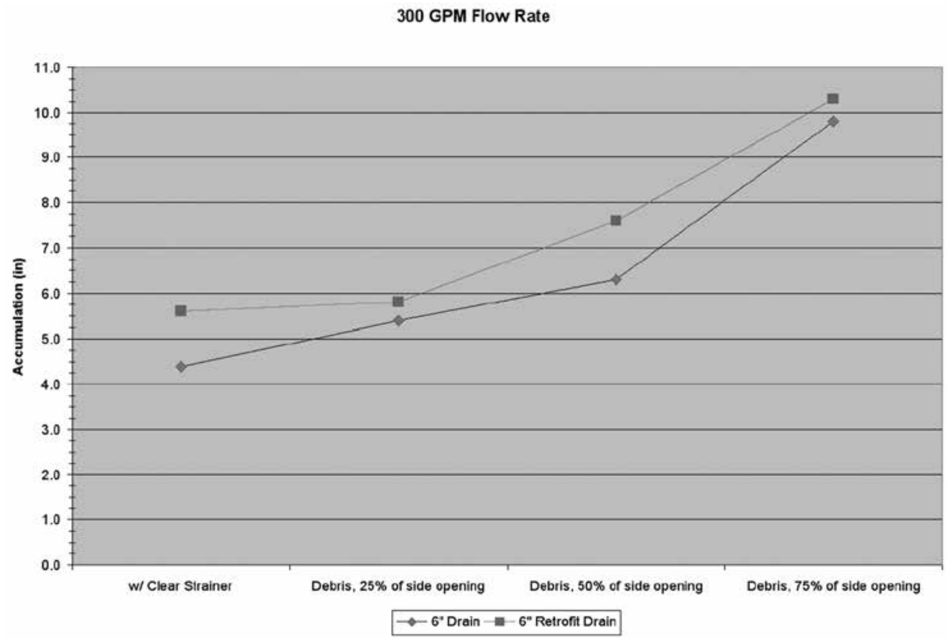


Figure 1 – Comparison of 6-in. drain with and without insert.

SCUPPERS

The study of flow rates through rectangular perimeter openings, scuppers, or weirs is a common subject in the study of fluid dynamics.[6] Scuppers can be constructed with either an open top (a channel) or a closed top with four sides. The theoretical flow of water through channels has been reported by Griffin and Fricklas. (See *Figure 2*.)

Other groups have reviewed the properties of flow-through scuppers, including the American Society of Civil Engineers (ASCE)[7] and RCI, Inc.[8] Theoretical flow rates have been published for various channel/scupper configurations.

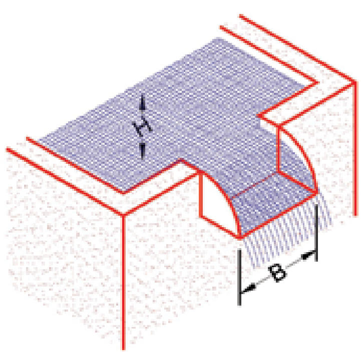
Four different sizes of through-wall scuppers were utilized for this study:

- 6 in. x 6 in.
- 6 in. x 9 in.
- 6 in. x 12 in.
- 6 in. x 24 in.

The scuppers were initially flooded with water at rates of 100 to 800 gpm until steady-state conditions were reached. Each configuration was tested with a clear opening and then partially obscured at rates of 25%, 50%, and 75%. The height of water accumulation for each combination of factors was measured. Data generated from the testing of the scuppers are included in *Table E*.

From a fluid dynamics standpoint, the flow rate characteristics change as the depth or accumulation of water increases. As the scupper is flooded, the water depth is less than the vertical element of the scupper. Water flows as in an open-sided channel. Once the scupper becomes submerged, the flow rate characteristics change as a result of the increased hydraulic head and the friction with all four sides of the scupper.

Scupper flow rate characteristics are not



$$Q = 3.33(b - 0.2H)H^{1.5}$$

Q = scupper capacity (ft.³/s)
b = scupper width (ft.)
H = hydraulic head (ft.) (assumed equal to scupper height)

Figure 2 – The theoretical flow of water through channels has been explained by Griffin and Fricklas.

SCUPPER FLOW RESEARCH

Laboratory Roof Scupper Flow Testing, Water Level, Height in Inches

Scupper Opening Dimensions: 24 in. Wide x 6 in. High

Condition – Approx. Flow Rate, gpm	Open Area, in.^{2}	100	200	300	400	500	600	700	800
Clear opening	144	2.5	3.0	3.5	3.9	4.4	4.8	5.2	5.8
Debris, 25% of side opening	108	3.9	4.3	4.7	5.3	5.6	6.0	6.5	6.9
Debris, 50% of side opening	72	5.6	5.8	6.0	6.5	6.8	7.3	8.2	9.3
Debris, 75% of side opening	36	5.7	6.9	8.7	11.4	12.7	13.8	>17	>17

Scupper Opening Dimensions: 12 in. Wide x 6 in. High

Condition – Approx. Flow Rate, gpm	Open Area, in.^{2}	100	200	300	400	500	600	700	800
Clear opening	72	3.3	4.0	4.8	5.9	6.5	7.1	8.2	9.1
Debris, 25% of side opening	54	4.5	5.3	5.9	6.8	7.9	8.9	10.7	12.8
Debris, 50% of side opening	36	6.0	6.8	7.7	9.4	11.9	15.0	<17	<17
Debris, 75% of side opening	18	10.3	12.4	16.8	<17	<17	<17	<17	<17

Scupper Opening Dimensions: 9 in. Wide x 6 in. High

Condition – Approx. Flow Rate, gpm	Open Area, in.^{2}	100	200	300	400	500	600	700	800
Clear opening	54	4.0	4.8	5.6	6.8	7.9	8.9	11.6	13.2
Debris, 25% of side opening	40.5	5.1	6.0	7.4	9.0	10.4	11.9	15.0	<17
Debris, 50% of side opening	27	6.9	7.8	10.7	14.0	15.8	<17	<17	<17
Debris, 75% of side opening	13.5	12.3	16.1	<17	<17	<17	<17	<17	<17

Scupper Opening Dimensions: 6 In. Wide x 6 In. High

Condition – Approx. Flow Rate, gpm	Open Area, in.^{2}	100	200	300	400	500	600	700	800
Clear opening	36	5.0	6.3	7.7	9.5	11.5	13.8	>17	>17
Debris, 25% of side opening	27	5.8	7.0	9.6	12.5	13.6	14.3	>17	>17
Debris, 50% of side opening	18	8.7	10.9	15.8	>17	>17	>17	>17	>17
Debris, 75% of side opening	9	>17	>17	>17	>17	>17	>17	>17	>17

Table E

Percentage of Primary Drain Blockage	Percentage of Secondary Drain Blockage	Approximate Discharge at Roof Drain (gpm)	Approximate Discharge at Scupper (gpm)	Approximate Accumulation at Roof Drain, Hydraulic Head (in.)
0	0	269	48	3.9
25%	0	264	53	5.1
50%	0	211	106	6.1
75%	0	151	166	7.1
100%	0	0	317	9.0
100%	25%	0	317	11.0
100%	50%	0	317	17.2
100%	75%	0	317	>18

Table F – Accumulation depending on blockage of test drain.

included within the building codes. In order to design a scupper with sufficient capability to match the drainage requirements of the primary roof drainage system, reverse engineering may be required using either actual testing or available theoretical flow rate data.

PRIMARY – SECONDARY DRAIN MODEL

One scenario was studied based on test data: a 6-in. primary drain with ¼-in. horizontal leaders located in Orlando, Florida. Prior data show one drain for 6,795 sq. ft. of roof. In this situation, 317 gallons of water per minute would be generated during a 4.5-in.-per-hour rainfall event. If the secondary drainage system consists of 6- by 6-in. through-wall scuppers (1 in. higher than the primary drain), then the following accumulation would develop, depending upon the percentage of debris present at the primary roof drain. (See *Table F*.)

Based upon test data, a 6- by 6-in. through-wall scupper may not be sufficient, depending upon the live-load capability of the structural deck. When the primary roof drain is blocked, water accumulates up to 9 inches. This amount of water would create a live load that could not be supported by most structural decks.

CONCLUSIONS

Several conclusions can be reached as a result of this study:

- Compliance with code requirements for drainage in new roofing and reroofing is critical for proper roof performance.
- In geographical areas prone to hurricane events, designers should consider increasing the capacity of the drainage system due to potential blockage as a result of airborne debris.
- Periodic roof maintenance, including debris removal, is necessary for proper roof drain and scupper performance. Removal of debris from the roof surface is the responsibility of the owner.
- "Green" roof assemblies most likely will require increased debris removal to ensure proper and consistent drainage.
- Width is the dominant factor in flow-rate performance of roof scuppers.
- The use of roof scuppers as the primary and secondary drainage systems may require reverse engineering to determine the proper height and size. Flow rates through scuppers obviously are dependent upon the height of the water accumulation. The depth of water and subsequent loading of the roof structure should be taken into consideration by the building designer.

REFERENCES

1. Eddie Garcia, "Got Drain?," *Western Roofing*, July 2009.
2. C.W. Griffin and R. Fricklas, "Draining the Roof," Chapter 3, *Manual of Low-Slope Roof Systems*, McGraw Hill, 2006.
3. International Building Code, 2006.
4. International Plumbing Code, 2006.
5. ANSI/SPRI RD-1, *Performance Standard for Retrofit Roof Drains*, April 7, 2004.
6. Frank M. White, *Fluid Mechanics*, Fifth Edition, McGraw Hill, 2003.

7. American Society of Civil Engineers, *Flow Rate of Various Drainage Systems at Various Hydraulic Heads*, ASCE 7-02, Page 338.
8. RCI Foundation, *Roof Drainage*, Publi-cation No. 02.03.

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— Dallas Goes Green With Building Regulations —

New mandatory green building regulations went into effect on October 1, 2013, in Dallas, Texas, intended to aggressively cut energy and water use with a goal of reaching carbon neutrality by 2030. The regulations are the culmination of the five-year Dallas Green Building Construction Ordinance for all new residential and commercial buildings.

New construction projects must meet either Leadership in Energy and Environmental Design (LEED®), Green Built Texas, or International Green Construction Code (IgCC) certification requirements.

To combat ongoing droughts, the regulations require that 70% of the built area for new homes either be permeable or capture runoff. All new homes may only use drip irrigation systems and must have high-efficiency fixtures. Commercial buildings are required to reduce water use by 20%, restrict outdoor lighting, and use cool or green roofing systems. New construction must divert at least 50% of waste material from landfills; and 45% of materials must be recycled, recyclable, bio-based, or locally sourced materials. Developers are required to pass a green builder certification exam.

The new regulations are expected to boost the regional economy, as building asset values rise when builders invest in sustainable development. To date, Dallas has more than 140 LEED-certified buildings, and 59 million sq. ft. of Energy Star-certified space.

— Cleantechnica.com

Rooftop PV Systems Getting Cheaper

According to a September report by the Solar Energy Industries Association (SEIA) and GTM Research, "the average cost of a solar panel...has dropped by 60% since 2011. The average residential PV system now costs only $4.81/watt, and the average nonresidential system costs only $3.71/watt."

SolarCity, Verengo and Wall, and Trinity Solar have emerged as the leading mass-market installers, for a combined 29.8% of the residential solar installation market in 2012.

At the same time, electric utilities, concerned that widespread installation of rooftop solar will reduce demand for utility-supplied electricity, are exploring how to enter the market.

In many states, laws allow only regulated utilities to sell power to customers. That remains a major hindrance to the expansion of rooftop solar across the U.S. Rooftop-solar leasing is thriving in states such as Arizona, Colorado, and Masschusetts, but it is illegal in most of the Southeast.

Competition is growing. Jonathan Bass, spokesman for SolarCity in San Mateo, CA, says companies will have to include high levels of customer service, fast and simple installation, and solar-power costs that are lower than what customers get from their local utilities.

— ENR