ASPE 45-20XX: Siphonic Roof Drainage

ASPE/ANSI 45-2018: SIPHONIC ROOF DRAINAGE (NORMATIVE)

1.0 GENERAL

1.1 Scope

1.1.1 This Standard applies to engineered siphonic roof drainage systems intended to prime and operate full-bore through proper pipe dimensioning and the use of siphonic roof drains.

1.1.2 This Standard shall not apply to atmospheric roof drainage systems, or sanitary drainage systems.

1.1.3 Local building and plumbing code requirements for pipe cleanouts, changes in direction, pitch of the piping and prohibitions for reductions in pipe size in the direction of fluid flow shall not apply to siphonic roof drainage design.

1.1.4 Pipe and drain sizing methodologies prescribed in locally adopted state plumbing codes shall not apply to the pipe sizing of siphonic roof drainage systems.

1.2 Purpose

1.2.1 The purpose of this consensus Standard is to establish the minimum performance specifications for siphonic roof drainage systems.

1.2.2 This consensus Standard provides designers, installers, and code officials with a standard of practice for the proper application of siphonic roof drainage.

1.2.3 This consensus Standard defines the terms and parameters involved in the proper design of siphonic drainage systems.

1.2.4 This consensus Standard provides guidelines for the inspection and testing of siphonic roof drainage installations.

1.2.5 This consensus Standard describes the basis for the design and manufacturer of siphonic roof drain products as well as the procedures for performance tests and publication of performance data to be used by siphonic roof drainage system designers.

1.3 Units of Measurement

1.3.1 Values are stated in U.S. Customary Units and in the International System of Units (SI). The International System Units shall be considered as the standard.

1.4 Illustrations

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1.5 References

1.5.1 The following standards are referenced in this document.

1.5.2 The listing of a reference in this consensus Standard shall imply the application of the latest issue, revision, or affirmation including all referenced documents listed therein.

1.5.3 Many standards, codes, and references include versions in both U.S. Customary Units and SI Units. For the purposes of this Standard, both versions apply.

1.5.4 American National Standards Institute (ANSI)

ANSI A21.10: ANSI Standard for Ductile-Iron and Gray-Iron Fittings

ANSI B16.5: Flanges and Flanged Fittings

ANSI B16.12: Cast Iron Threaded Drainage Fittings

ANSI B16.18: Cast Copper Alloy Solder Joint Pressure Fittings

ANSI B16.22: Wrought Copper and Copper Alloy Solder Joint Pressure Fittings

ANSI B16.23: Cast Copper Alloy Solder Joint Drainage Fittings—DWV

ANSI B16.29: Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings—DWV

ANSI B16.42: Ductile Iron Pipe Flanges And Flanged Fittings, Classes 150 and 300

ANSI B36.10: Standard Dimensions of Steel Pipe (IPS)

1.5.5 American Society of Civil Engineers (ASCE)

ASCE 7: Minimum Design Loads for Buildings and Other Structures

1.5.6 American Society of Mechanical Engineers (ASME)

ASME A112.6.9: Siphonic Roof Drains

Boiler and Pressure Vessel Code, Section VIII, Division 1

1.5.7 American Society of Sanitary Engineering (ASSE)

ASSE 1045: Aluminum Drain, Waste, and Vent Pipe with End Cap

1.5.8 American Society for Testing and Materials (ASTM)

ASTM A53: Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

ASTM A74: Specification for Cast Iron Soil Pipe and Fittings

ASTM A153: Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

ASTM A312: Specification for Seamless and Welded Austenitic Stainless Steel Pipes

ASTM A395: Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures

ASTM A377: Index of Specifications for Ductile-Iron Pressure Pipe

ASTM A395: Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures

ASTM A774: Specification for As-Welded Wrought Austenitic Stainless Steel Fittings for General Corrosive Service at Low and Moderate Temperatures

ASTM A888: Specification for Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste, and Vent Piping Applications

ASTM B32: Specification for Solder Metal

ASTM B75: Specification for Seamless Copper Tube

ASTM B828: Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings

ASTM C1540: Standard Specification for Heavy Duty Shielded Couplings Joining Cast Iron Soil Pipe and Fittings

ASTM D638: Test Method for Tensile Properties of Plastics

ASTM D695: Test Method for Compressive Properties of Rigid Plastics

ASTM D696: Test Method for Coefficient of Linear Thermal Expansion of Plastics Between -30°C and 30°C With a Vitreous Silica Dilatometer

ASTM D1527: Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe, Schedules 40 and 80

ASTM D1599: Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tube and Fittings

ASTM D1600: Terminology for Abbreviated Terms Relating to Plastics

ASTM D1785: Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120

ASTM D2104: Specification for Polyethylene (PE) Plastic Pipe, Schedule 40

ASTM D2235: Standard Specification for Solvent Cement for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe and Fittings

ASTM D2241: Specification for Poly (Vinyl Chloride) (PVC) Pressure Rated Pipe (SDR Series)

ASTM D2447: Specification for Polyethylene (PE) Plastic Pipe, Schedules 40 and 80, Based on Outside Diameter

ASTM D2657: Practice for Heat-Joining Polyolefin Pipe and Fittings

ASTM D2661: Specification for Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe and Fittings

ASTM D2665: Specification for Poly (Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings

ASTM D2855: Practice for Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings

ASTM D3261: Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing

ASTM D3350: Specification for Polyethylene Plastics Pipe and Fittings Materials

ASTM E84: Test Method for Surface Burning Characteristics of Building Materials

ASTM E132: Test Method for Poisson's Ratio at Room Temperature

ASTM E412: Terminology Relating to Plastic Piping Systems

ASTM E814: Test Method of Fire Test for Through Penetration Fire Stops

ASTM F714: Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter

ASTM F1866: Specification for Poly (Vinyl Chloride) (PVC) Plastic Schedule 40 Drainage and DWV Fabricated Fittings

ASTM F1901: Specification for Polyethylene (PE) Pipe and Fittings for Roof Drain Systems

1.5.9 American Water Works Association (AWWA)

C110: Standard for Ductile-Iron and Gray-Iron Fittings, 3 In.-48 In. (76 mm-1,219 mm), for Water

C606: Grooved and Shouldered Joints

1.5.10 Cast Iron Soil Pipe Institute (CISPI)

Designation 301: Standard Specification for Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste and Vent Piping Applications (ASTM B888)

CISPI 310: Specification for Coupling for Use in Connection with Hubless Cast iron Soil Pipe and Fittings for Sanitary and Storm Drain Waste, and vent Piping

1.5.11 Copper Development Association (CDA)

Copper Tube Handbook

1.5.12 Crane Technical Paper No. 410, “Flow of Fluids Through Valves, Fittings and Pipe,” 1988

1.5.13 International Organization for Standardization (ISO)

ISO 899: Plastics – Determination of Tensile Creep Behavior

1.6 Definitions and Nomenclature

1.6.1 Definitions

Adiabatic Characteristic of a process absent of the loss or gain of heat energy to or from the environment.

Air Baffle A device that limits the flow of air into a drain, causing the connected drainage piping to run at full-bore flow with a limited water depth on the roof surface.

Allowable Negative Pressure The minimum allowable pressure for a pipe segment established to avoid either cavitation or pipe collapse.

Architect The party responsible to an owner for the design of a structure or facility and who may retain the services of an engineer for the purposes of designing a siphonic roof drainage system. Synonymous with “Designer.”

Bernoulli Equation Common name for the fluid energy equation. An energy balance equation demonstrating the conservation of three major energy states—static pressure energy, kinetic energy (velocity pressure), and potential energy. Also referred to as “Bernoulli’s Principle.”

Closed Flow Characteristic of a system of piping and piping components that isolates the internal fluid pressure from the surrounding or external atmosphere.

Colebrook-White Equation The governing equation used to calculate the expected friction loss factor (f) used in the Darcy-Weisbach Equation. The equation is a function of pipe surface roughness, pipe diameter, fluid viscosity, and fluid velocity.

Cricketing A small false roof, or the raising of a portion of a roof, so as to throw off water from behind an obstacle, such as roof equipment, or to divide water flow as to roof drains or scuppers.

Critical (Buckling) Pressure The external pressure limit created by sub-atmospheric internal pressure in a pipe segment at which the pipe wall would deform or collapse.

Darcy-Weisbach Equation The governing equation used to calculate the expected energy loss due to friction caused by viscous fluid flow through a length of straight pipe or duct.

Designer Synonymous with “architect” or “engineer.”

Disposable Head The difference in elevation between the surface of the water on the roof (or drain rim elevation) and the point of discharge at grade level. This is the potential energy available to the system.

Drain Outlet The part of a siphonic roof drain configured to connect to the tailpiece with a standard coupling device.

Eccentric reducer A fitting which allows for a change in pipe diameter while maintaining the top (or one side) of the pipe level or straight.

Engineer As agent of the architect or owner, is the party responsible for the design of a siphonic drainage system to meet operating and safety standards. For the purposes of this Standard, an engineer is licensed in the jurisdiction in which this Standard is being applied as a Professional Engineer (PE) in the discipline of mechanical or civil engineering.

Engineered Design The detailed design for a siphonic roof drainage system, developed from the building drainage requirements and conforming to Standard requirements, including the necessary drawings and specifications.

Equivalency Meeting the intent of a building code or plumbing code for minimum performance, safety, reliability, fire resistance, and longevity, but using a different method, concept, or design than that prescribed in the building code or plumbing code.

Full-Bore Flow Flow of water in a pipe where theoretically 100% of the cross-section of the pipe bore is filled. In practical terms, full-bore flow is regarded as achieved at water content greater than 95% by volume.

Imbalance The difference between the maximum and minimum residual head between drains connected to a stack.

Inspection Any operation performed to assure the owner that the materials, components, fabrication, and installation are in accordance with the engineering design. Inspection may include review of certifications and records of examinations and testing and any examination that may be required by the Designer’s specifications.

Inspector The owner, or a person representing the owner (not employed by the manufacturer, fabricator, or erector when different from the owner), who performs an inspection.

Inviscid Having no viscous properties (i.e., $n = 0$).

Owner The party engaging the services of the architect and contractor for the purposes of constructing a structure within which it will realize beneficial occupancy.

Residual Head The difference between the calculated energy losses through the pipe system (from the drain inlet to the point of discharge) and the available disposable head.

Section The complete pathway of piping from a single roof drain to the point of discharge. The number of sections in a system typically equals the number of drains on the roof.

Section Part An individual pipe length of constant diameter, fitting, or flow (velocity) in a section. As several roof drains may tie into a single point of discharge, sections of a system may share several section parts.

Single Resistance Value (Ki) A coefficient that is characteristic of a pipe fitting’s or drain’s contribution to energy losses.

Siphonic (Syphonic) Roof Drainage A closed-flow roof drainage system operating under gravity-induced sub-atmospheric pressures based on the vertical differential fluid head principle (the height of a column of water expressed in pounds per square inch pressure or equivalent metric units).

Stack The vertical section part(s) conveying water from the main overhead collection piping to the lower levels.

Streamline An imaginary line along the flow path of a fluid that is everywhere tangent to the velocity vector of the fluid at any given instant.

Tailpiece The section part(s) connecting the drain outlet to the main collection piping.

1.6.2 Nomenclature

A = drainage area, m^2 (ft^2)

α = angular measurement, degrees

C = surface runoff coefficient, dimensionless

C_{tx} = coefficient of thermal expansion/contraction, cm/cm/°C (ft/ft/°F)

cfs = cubic feet per second

d = pipe inner diameter, mm (in.)

D = pipe inner diameter, m (ft)

Δ = delta (“change in,” “difference”)

E_c = creep modulus, MPa (psi)

E_t = long-term tensile elastic modulus, MPa (psi)

ε = pipe surface absolute roughness value, m (ft)

f = Colebrook-White friction factor, dimensionless

F = force, Newtons (lbf)

FS = factor of safety, dimensionless

ft = feet

g = gravitational constant, 9.8 m/s^2 (32.2 ft/s^2)

gpm = gallons per minute

h_f = energy loss due to flow resistance, m H_20 (ft H_20)

h_i = system imbalance, m (ft)

h_r = residual head, m (ft)

h_t = energy loss due to friction in a single component, m (ft)

h_{vp} = vapor pressure, m H_20 (ft H_20)

I_d = Design rainfall intensity of siphonic system, mm/hr (in./hr)

I_r = storage capacity of a roof L(Gal)

I_s = statistical rainfall intensity for a given return period, mm/hr (in./hr)

in = inches

K_i = single resistance value, dimensionless

L = pipe length, m (ft)

L_y = design life span of a building, years

lb_f = pounds, force

lb_m = pounds, mass

m = mass, kg (lbm)

n = number of fittings

μ = Poisson’s ratio (dimensionless)

P = static pressure, m H_20 (lb_f/ft^2 or ft H_20)

P_a = atmospheric pressure, m H_20 (lbf/ft^2 or ft H_20)

P_{cr} = critical pressure (also “buckling pressure”), MPa (psia)

P_{al} = allowable pressure, MPa (psia)

P_e = external pressure, MPa (psia)

P_i = internal pressure, MPa (psi)

P_r = probability of exceeding the statistical rate of rainfall

p = static pressure, m H_2O (lbf/in^2 or psi)

Q = volumetric flow, ~~lps~~ l/s (cfs)

ρ = fluid density, kg/cm^3 (slug/ft^3)

Re = Reynold’s number, dimensionless

R = mean pipe radius (R = [D-t]/2), mm (in.)

s = second

T = return period of a storm event, years

t = pipe wall thickness, mm (in.)

t_d = time of storm event duration, minutes

V = fluid velocity, m/s (ft/s)

v = fluid kinematic viscosity, ft^2/s

ψ = ratio of volumetric flow rate of water to total volumetric flow, dimensionless

w.c. = water column, m (ft)

Z = fluid elevation, m (ft)

Z_e = elevation of point of discharge, m (ft)

Z_i = the water level on the roof m(ft)

i = inlet

e = discharge

I_a = Actual Rainfall Intensity mm/hr (in/hr)

x = arbitrary point along the section being evaluated.

Q_T = Flow capacity of tailpipe when acting siphonically and discharging to collector pipe at atmospheric pressure

V_P = Volume of Pipe L (ft^3)

T_F = Filling Time (Seconds)

T_l = Time of Loading (Minutes)

dm/dt = mass flow rate in kilograms per second (slugs per second)

2.0 ACCEPTABLE MATERIALS AND COMPONENTS

2.1 Siphonic Roof Drains

2.1.1 All roof drains used in a siphonic roof drain system shall comply with ASME A112.6.9.

2.2 Pipe, Fittings, and Couplings

2.2.1 All materials, fittings, and joining methods used in the construction of siphonic roof drainage systems shall comply with the material and product standards listed in this Standard under Table 2.1.

Table 2.1: Acceptable Materials and Components

Material	Pipe Standard	Wall Thickness	Fitting Standard	Joint Standard
Cast Iron	ASTM A888 CISPI 301	ASTM A888	ASTM A888	Note 1 CISPI 310 ASTM C1540
Ductile Iron	ASTM A377	Class 50 Class 51	ANSI A21.10 ANSI B16.42 AWWA C110	ANSI B16.5 ANSI B16.42 ASTM A395 AWWA C606A Note 3
Steel, Stainless, AISI Type 304 AISI Type 316	ASTM A312	Schedule 5 Schedule 10 Schedule 40	ASTM A774	ASTM A395 Note 3
Steel, Galvanized	ASTM A53	Schedule 5 Schedule 10 Schedule 40	ASTM A153 ANSI B16.12	ASTM A395 ANSI B16.5 Note 3
Copper	ASTM B75 ASTM B88	Type M, L, K	ANSI B16.29	ASTM A395 ASTM B32 ASTM B828 Note 3
ABS	Note 2 ASTM D2661	Schedule 40	ASTM D2661	ASTM D2235
HDPE	~~ASTM D2104~~ ~~ASTM D2447~~ ~~ASTM D3350~~ ASTM D3035 ASTM F714	Schedule 40 SDR 21	ASTM D3261	ASTM D3261 ASTM D2657
PVC	ASTM D2665 CAN/CSA-B181.2 CAN/CSA-B181.4 ASTM D1785 Note 2	Schedule 40 Schedule 80	ASTM D2665	ASTM D2855 Note 3

1. Joint thrust restraint is required when the operating pressure exceeds atmospheric pressure 0.1 MPa (14.7 psia).
2. Cellular core pipe is prohibited.
3. All Groove joint gaskets shall be rated for the pressures within the system.

2.2.2 Pipe material selection shall also be in conformance with local building and plumbing codes. Pipe materials or products not approved by local building or plumbing codes shall not be used unless the Designer obtains local authority approval.

2.2.3 All materials shall be installed in accordance with the standards (including referenced standards) under which the materials are accepted and approved and in accordance with manufacturers' written instructions.

2.2.4 Only standard fittings and components listed under the applicable ASTM standard shall be used. All pipe fittings shall be of the drainage, waste, and vent (DWV) type. ~~except~~ Exception: ~~that non~~ Non-DWV ~~fittings limited to~~ 45-~~-~~d~~D~~egree bends and reducers shall be allowed~~, when~~ where DWV fittings are not available.

2.2.5 All changes in direction in the horizontal plane shall be sweep radius elbows or a combination of eighth-bend elbows or an eighth-bend elbow and lateral wye.

2.2.6 Change from vertical to horizontal shall be sweep radius elbows or a combination of eighth-bend elbows. If combinations of eight-bend elbows are used, they should be directly connected without a pipe section between them.

2.2.7 Pipe increasers in horizontal pipes and reducers at the top of risers shall be of the eccentric configuration. If listed pipe materials and products are not commercially available, concentric fittings are permitted. Other than at the top of the riser, concentric reducers may be used on vertical pipes.

2.3 Expansion Joints

2.3.1 If the pipe material used does not have expansion joints available to withstand system pressures, expansion loops may be used and incorporated in design calculations.

2.3.2 The inherent tolerances in some roll-groove or cut-groove mechanical joints may be utilized when allowing for pipe thermal expansion or contraction.

2.3.3 Mechanical expansion joints installed in siphonic roof drainage systems shall be capable of withstanding both positive and negative pressure conditions.

2.3.4 Mechanical expansion joints used in siphonic roof drainage systems shall have a smooth inner bore without internal bellows or other restrictions and pockets where debris may accumulate.

3.0 CONCEPTUAL OVERVIEW

3.1 A siphonic roof drainage system consists of siphonic roof drains with air baffles complying with ASME A112.6.9 connected to horizontal and vertical piping that is designed to prime completely full of water and depressurize at the upper region of the system. The air baffles in the drains prevent the ingestion of air at design rainfall intensity. The energy of the system comes from the full height of the roof above the point of discharge—not the small upstream depth of water ahead of the drain and the slope of the pipe. ~~The driving hydraulic head of the system becomes the full height of the roof above the point of discharge—not the upstream depth of water ahead of the drain.~~ Siphonic systems, therefore, have inherently higher flow capacities for the same pipe size and velocities that can be taken advantage of by Designers in several ways:

3.1.1 No pitch requirement of piping to induce flow,

3.1.2 Flexibility in the placement of stacks,

3.1.3 Smaller pipe diameters, and

3.1.4 Easier coordination of piping with other building elements.

3.2 Siphonic systems operate on different hydraulic principles than conventional systems. Siphonic system design requires a higher level of technical understanding on the part of the Designer, and greater precision is required from both the Designer and the Installer.

3.3 The performance of siphonic roof drains and the connected drainage system is related directly to the pipe configuration. To ensure correct application of siphonic roof drainage in buildings, this Standard provides guidance to Designers knowledgeable in the principles of fluid mechanics and fluid dynamics in order to establish standard design methodologies developed through past experience and the evaluation of successfully operating systems.

4.0 SIPHONIC THEORY

4.1 General

4.1.1 This Standard is not intended to exclude or prohibit the application of new principles developed from scientific research. Such findings shall be substantiated by practical flow tests consistent with the dynamic conditions and boundary conditions of siphonic roof drainage pipe installation and documented in writing. Such application shall be at the discretion of the Designer.

4.1.2 Although the priming and depressurization phases must be understood by the Designer to achieve a design that will prime, the primary focus of the system design is during the steady-state depressurized condition where the piping is flowing at full-bore with little or no entrained air (i.e., air content less than 5% by volume).

4.1.2.1 Pipe systems operating with air content greater than 5% are regarded as being in a transient, partially primed state either advancing toward full-bore flow or receding to a part-filled atmospheric flow pattern.

4.1.2.2 If calculation procedures used by a Designer include the analysis and/or control of air content in the fluid flow during siphonic operation, then the calculated water ratio, ψ, shall be 0.95 or greater in all section parts.

4.1.3 Designer Caveat: The use of the Hazen-Williams Formula for siphonic roof drainage design has been found to be not sufficiently accurate to consistently meet the required design tolerances for siphonic roof drainage. The Hazen-Williams Formula is an empirical equation used by Designers to estimate frictional losses caused by fluid flow and is valid for water at a temperature of 15.6°C (60°F) and at velocities less than 3.0 m (10 ft) per second. The Hazen-Williams Formula shall not be used for siphonic roof drainage design.

4.1.4 The theoretical basis of fluid dynamics outlined in Sections 4.2 through 4.5 shall be applied to siphonic drainage systems.

4.2 The Energy Equation (Bernoulli’s Equation)

4.2.1 Bernoulli’s Equation is one of the fundamental equations of fluid mechanics and is the primary equation upon which siphonic drainage design is based.

4.2.2 The equation is an energy balance relationship stating that a fluid in either rest or in motion possesses three fundamental forms of energy. A fluid has a static pressure energy that represents the work performed to compress the fluid system. It also has a kinetic energy that represents the work performed on the fluid system to bring the fluid from rest to a certain velocity. Finally, the fluid also possesses a potential energy as a result of its elevation in a gravity field. The sum of these three energy states, according to Bernoulli, is conserved even though the system energy states may be transferred from one form to another. The form of Bernoulli’s Equation used here makes three main assumptions:

(1) The fluid is incompressible and inviscid.

(2) No work is done on the system or performed by the system.

(3) The system is adiabatic.

4.2.3 Bernoulli’s Equation is expressed as follows:

Equation 4.1

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

4.2.3.1 The subscripts 1 and 2 represent two locations along a streamline or two process end states within the fluid system.

4.3 The Darcy-Weisbach Equation

4.3.1 The inviscid (i.e., frictionless) assumption of Bernoulli is intended to demonstrate a basic principle of energy conservation. However, real fluid flow through a pipe, drain, or fitting comes at the expense of irreversible energy losses normally referred to as friction.

4.3.2 The accepted equation used to calculate the expected energy loss in a fluid system as a result of fluid flow is the Darcy-Weisbach Equation. This equation is expressed as follows:

Equation 4.2

$$h_f = f\left(\frac{L}{D}\right)\frac{V^2}{2g}$$

4.3.3 This equation evaluates energy loss (expressed in feet of fluid).

4.3.4 The friction factor (f) in the Darcy-Weisbach Equation is evaluated using the Colebrook-White Formula:

Equation 4.3

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left[\frac{2.51}{Re\sqrt{f}} + \frac{\varepsilon}{3.71D}\right]$$

4.3.4.1 Where: $Re = VD/\nu$

4.3.4.2 The Colebrook-White Formula is valid for Reynolds Numbers in the turbulent regime (i.e., Re > 2,000 to 4,000). Below this range, f can be evaluated simply as $f = 64/Re$. However, in siphonic drainage design, the turbulent regime is always true (see Section 7.9 “Minimum Velocity”), and the Colebrook-White Formula prevails in energy loss analysis.

4.3.4.3 The value of absolute roughness (ε) varies with pipe material and manufacturer. The Designer shall verify the appropriate roughness value for the selected pipe material(s) from standard engineering references or manufacturer data.

4.3.4.4 The absolute roughness value (ε) is not the same as that used with the Hazen-Williams Formula.

4.4 Other Energy Losses

4.4.1 Each segment of pipe, each fitting, and each roof drain contribute to friction losses, and the total loss through the pipe system (i.e., section) is the summation of the losses through each component.

4.4.2 Each drain and fitting has a single resistance value that is determined experimentally. The losses produced by these components is expressed as follows:

Equation 4.4

$$h_t = K_i\left(\frac{V^2}{2g}\right)$$

4.4.3 Values for K_i are available from fitting manufacturer data or standard engineering references.

4.4.4 The K_i value for a particular type of fitting or component varies with pipe material and manufacturer. Refer to manufacturer data for appropriate single resistance values.

4.4.5 Resistance values also include the energy losses experienced by the merging of two fluid streams at a juncture in the piping system. The energy losses at these junctions are a function of the merging flow rates, pipe diameters, and angle of merger and shall be incorporated into the Designer’s calculations.

4.4.6 Siphonic drains shall be tested for head loss vs. flow rate to determine their specific resistance values.

4.4.7 ~~Refer to manufacturers’ published data for the single resistance values of available drains.~~ Refer to manufacturers' published data for the single resistance value determined from testing according to ASME A112.6.9

4.5 The Siphonic Equation

4.5.1 ~~First, a~~A complete energy account can be written by combining Bernoulli's Equation 4.1 with the energy loss Equations 4.2 and 4.4:

Equation 4.5

$$\frac{P_i}{\rho g}+\frac{V_i^2}{2g}+Z_i=\frac{P_e}{\rho g}+\frac{V_e^2}{2g}+Z_e+\sum_{j=1}^{m}(h_f)_j+\sum_{k=1}^{n}(h_t)_k$$

4.5.1.1 The energy state at the entrance of the roof drain is equal to the energy state at the point of discharge plus the sum of energy lost within each pipe segment, fitting, and component due to viscous fluid flow.

4.5.1.2 The summation nomenclature is intended to show the total contribution of irreversible energy losses (i.e., resistance to flow) for m number of pipe lengths and n number of fittings comprising a section.

4.5.2 Certain simplifications to Equation 4.5 are made specifically to siphonic roof drainage systems:

4.5.2.1 First, the static pressure (P) is atmospheric both at the water level on the roof and at the point of discharge at grade. Thus the static pressure term on either side of the energy relationship is cancelled out.

4.5.2.2 Second, the velocity of the water at roof level can be assumed to be insignificant compared to the water velocity at the point of discharge and the total amount of energy lost due to friction; therefore, the Vi term is assumed to be zero.

4.5.2.3 Third, the velocity head at the point of discharge can be considered an irreversible loss of energy as if it were a friction loss. By assigning a resistance value of Ki = 1 at the point of discharge, the velocity head term at the point of discharge can be combined with the sum of energy losses through fittings (h_t).

4.5.2.4 This leaves the following terms:

Equation 4.6

$$Z_i-Z_e-\sum_{j=1}^{m}(h_f)_j-\sum_{k=1}^{n+1}(h_t)_k=0$$

4.5.3 Equation 4.6 is the basis of siphonic drainage design.

4.5.3.1 The driving head of a siphonic system is the elevation difference between the water level on the roof and the point of discharge ($Z_i – Z_e$). This difference in height is referred to as the disposable head.

4.5.3.2 The n+1 nomenclature in the single resistance value term denotes the addition of discharge velocity head to the irreversible losses.

4.5.3.3 Since no other energy is added to or taken out of the system, the system irreversible losses plus the velocity head at the point of discharge must exactly balance the available energy of the system, which is the disposable head.

4.6 Flow Patterns in Siphonic Roof Drainage Systems

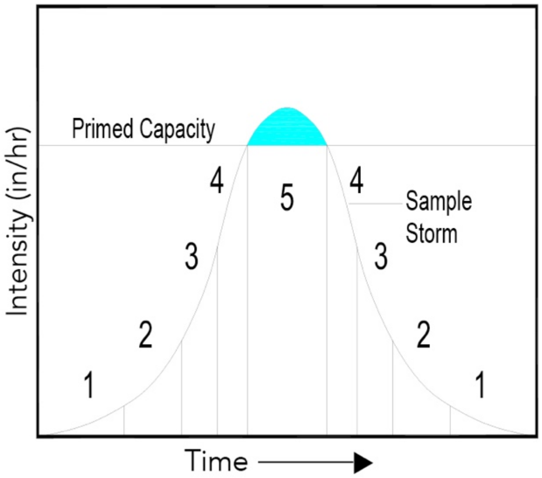
4.6.1 Although siphonic roof drainage systems are designed to operate under full-bore conditions, there are five distinct flow patterns that have been observed in laboratory testing.

4.6.2 The priming process is not instantaneous. It takes place in phases as rainstorm intensity develops. Refer to Figure 4.1 below.

4.6.3 The numbers 1 through 5 represent the observed flow patterns in siphonic systems during laboratory tests.

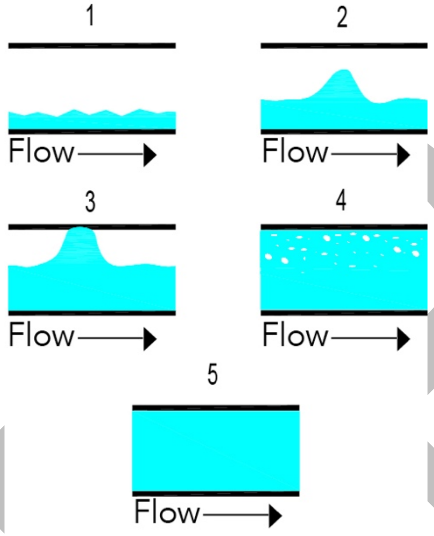
4.6.4 Figure 4.1 represents a design where the design rainfall intensity (I_d) (primed capacity) is less than the statistical rainfall intensity (I_s) of a storm of return period (T) and duration (t_d). The excess water (I_r) accumulates on the roof until the storm recedes or the point of overflow is reached.

Figure 4.1: Priming Process



4.6.5 Each flow pattern is illustrated in Figure 4.2 below:

Figure 4.2: Siphonic System Flow Patterns



4.6.6 Wavy flow (Pattern 1) is seen during rainfall events far below the piping system's ability to prime. Light showers will typically produce this flow condition until rainfall intensity increases to a point where tailpieces can fully prime.

4.6.7 The so-called pulsating flow (Pattern 2) ordinarily happens at the junctions of the tailpieces with the main collection piping. This is due to the sudden decrease in velocity as the water transitions from the smaller diameter tailpiece to the larger main collection pipe. At this juncture, a hydraulic jump occurs as the fluid flow transitions from super-critical to sub-critical. At this stage, sudden increases in velocities take place accompanied by decrease in pressures. Eventually the peaks of these hydraulic jumps come in contact with the crown of the pipe and begin to propagate downstream, and (if the design rainfall intensity continues) the plug flow pattern (Pattern 3) becomes prominent.

4.6.8 As the pipe system continues to fill, the percentage of air carried in the flow stream steadily decreases. When air content drops to about 40% by volume, siphonic action begins with the decrease in static pressures below atmospheric. As plug flow transitions to bubble flow (Pattern 4), the remainder of the entrained air in the piping becomes mixed with the water and is carried downstream to the point of discharge until full-bore flow is reached (Pattern 5). At this stage, the system's design drainage rate is attained.

4.6.9 Full bore flow (Pattern 5) is defined as water flow with air content less than 5% by volume.

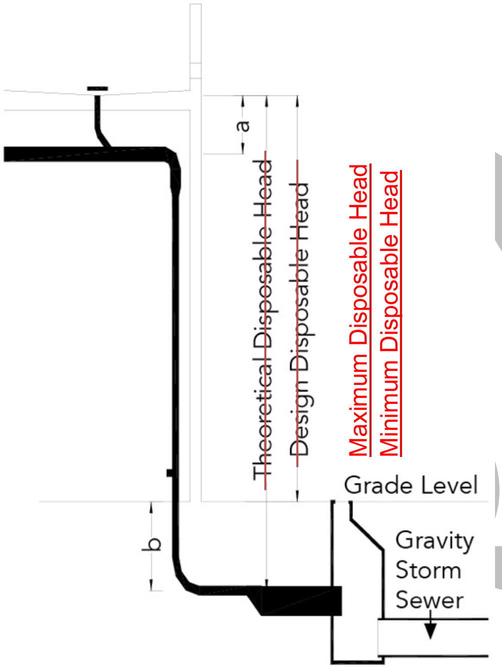
4.6.10 As the rainstorm event trails off in intensity, the piping system experiences the same flow patterns in reverse order until the system drains completely down.

4.7 Disposable Head

4.7.1 Theoretically, the difference in height between the water upstream of the roof drains and the point of discharge represents the hydraulic head that may be utilized in sizing the piping system in accordance with Equation 4.6.

4.7.2 The disposable head available to a system may vary between two fixed values, depending on the severity of the storm event, the configuration of the connected storm sewer, and the available capacity of the storm sewer. Refer to Figure 4.3.

Figure 4.3: Theoretical vs. Design Disposable Head



4.7.3 The maximum disposable head available to a system is the vertical difference between the roof drains (inlets) and the physical elevation of the point of discharge into the storm sewer system. When calculating the overall head loss of the system (friction), all vertical segments of pipes (segments (a) vertical tailpipe, (b) below grade vertical, and the main downpipe in Figure 4.3 above) shall be included. The pressure at the point of discharge is zero m w.c. (ft w.c.).

4.7.4 The minimum disposable head available to a system is the vertical difference between the roof drains (inlets) and the elevation of the grade level or other lowest elevation of spill-out to atmosphere. This accounts for the possible condition of the storm sewer being surcharged downstream either from heavy storm events or physical obstruction. When calculating the overall head loss (friction) of the system, all vertical segments of pipes (segments a, b, and the main downpipe in Figure 4.3 above) shall be included as in 4.7.3. The pressure at the point of discharge is the head pressure created by the water depth (b).

4.7.5 Calculate the required flow rate from the roof using the minimum disposable head available as described in 4.7.4. Verify system pressures and velocities are within the acceptable limits as laid out herein throughout the system, including minimum pressure to avoid cavitation.

4.7.6 Calculate the maximum flow rate from the roof using the maximum disposable head available as described in 4.7.3. Verify system pressures and velocities are within the acceptable limits as laid out herein throughout the system and verify minimum pressure in the system does not induce cavitation. Refer to Section 7.8.

5.0 DESIGN RAINFALL INTENSITY

5.1 General

5.1.1 The frequency and intensity of rainstorm events varies with geographic location.

5.1.2 The design layer of water on the roof both at siphonic operation and during the priming phase shall not exceed the design rain or snow load of the roof deck.

5.1.3 The setting of secondary overflow heights shall be coordinated with the structural design of the roof, as required by the code but must also allow enough water around the drains of the primary system to operate siphonically without reaching the overflow point.

5.1.4 The design rainfall intensity (I_d) is typically provided in the building code. In order to establish equivalency with the applicable building or plumbing codes, the design rainfall intensity shall be equal to or greater than the rainfall set by the applicable code or the authority having jurisdiction. Siphonic roof drain systems are designed with the same rainfall rates as conventional systems.

5.1.5 The design rainfall intensity for the secondary overflow system shall be similarly selected in accordance with the applicable code.

5.2 Water Depth on Roof and Roof Storage Capacity (I_r)

5.2.1 In any roof drainage system, a layer of rainwater will accumulate on the roof. In the case of conventional atmospheric roof drainage systems, this depth is determined by the rainfall intensity, total roof area, and the diameter of the drain and the shape and configuration of the drain body and strainer.

5.2.2 In siphonic roof drainage systems, the depth of water on the roof is a property of the roof drain product and the flow assigned to that drain under full siphonic conditions.

5.2.2.1 Refer to manufacturer's data for water depth on roof vs. flow.

5.2.2.2 Refer to ASME A112.6.9 for roof drain product test procedures to establish water depth vs. flow performance curves.

5.2.3 Therefore, there are four conditions that a siphonic roof drainage system will experience:

5.2.3.1 Rainfall intensity below the system's ability to prime. In this case, the water on the roof will enter the piping system through the siphonic roof drains and cascade down to the point of discharge like a conventional atmospheric drainage system.

5.2.3.2 Rainfall intensity above the system's ability to prime but below the full-bore flow rate induced by the fully primed system. In this case, the tailpieces are fully primed, and the stack and main collection piping can fill. However, the system will continue to operate with both air and water in the piping, occasionally ingesting air with flow rates below design flow.

5.2.3.3 Rainfall intensity exactly equal to the design rainfall intensity at full bore flow. In this case, a certain layer of water will be developed and maintain constant. This condition is rarely, if ever, achieved in reality for any significant period of time.

5.2.3.4 Rainfall intensity above the design rainfall intensity. In this case, rainwater will accumulate on the roof at a rate of $I_a – I_d$. The layer of water on the roof will accumulate until the storage capacity of the roof, I_r, is reached and the secondary drainage system relieves the excess water.

5.2.4 In all roof drain systems, the maximum depth of water on the roof, at the design rainfall intensity, shall be evaluated to determine where the level of the secondary overflow system should be set as well as to ensure the structural capacity of the roof deck or capacity of the gutter system is not exceeded.

6.0 DRAIN PLACEMENT AND CONNECTION

6.1 General

6.1.1 The Designer shall examine the drain layout on the roof. The guidelines in 6.1 apply to siphonic and conventional roof drainage

6.1.2 The total tributary area to each drain shall not exceed the drain maximum flow capacity at the design rainfall intensity, I_d. Refer to manufacturer performance data for maximum flow capacities for a drain product.

6.1.3 The design of roof drainage systems shall avoid undrained low points and accumulation of stagnant water that may adversely affect the durability of the roof.

6.1.4 Drain placement, spacing and size shall be dictated by the maximum desired layer of water on the roof required for the drain to achieve and sustain full-bore flow.

6.1.5 Refer to manufacturer's literature for the maximum capacity of the drain product specified. This determines the maximum roof surface area that the drain can cover at the design rainfall intensity. Thought should also be given always to the possibility of a drain becoming clogged or blinded, with the detained water flowing to adjacent drains prior to reaching overflow. The Designer should factor this into the drain selection and how much capacity should remain in reserve for each drain..

6.1.6 Roof areas should be at least large enough to collect sufficient water to achieve siphonic action during a design rainfall event. See sections 7.4 and 7.9. ~~Designers should also take into account minimum roof areas driven by minimum velocities at the design Rainfall intensity as defined in section 7.4 and 7.9~~

6.2 Gutters

6.2.1 Provide adequate drain quantities and spacing to allow the gutter to contain accumulating water while the connected piping system primes (i.e., during fill time).

6.2.2 The maximum depth of water in the gutter shall be evaluated at design rainfall intensity and may vary substantially from the results of testing per ASME A112.6.9 for a flat roof.

6.3 Flat Roofs

6.3.1 On flat roofs with parapets or where an added measure of structural protection is required, the roof drainage system (whether siphonic or conventional) ~~may~~ shall be backed up by a secondary overflow drain system or a parapet scupper system when required by the governing code. Where local code allows the connection of secondary drains into the primary piping system, the Designer shall provide a separate secondary system, as secondary drains connected to a primary siphonic system will cause air ingestion and prevent siphonic action.

6.3.2 Drains should be placed away from corners and other "dead" areas where debris may tend to accumulate.

6.4 Pitched Roofs

6.4.1 All roof structures are pitched to low points or valleys by the pitch of the structural roof framing system or tapered insulation.

6.4.2 See Section 6.3 "Flat Roofs" for drain placement.

6.4.3 On a pitched roof, drains might be placed at different elevations. The elevation shall be reflected in hydraulic calculations to verify residual head, imbalance, minimum pressure, etc.

6.4.4 On a pitched roof, drains shall be located within appropriately configured roofs, walls, cricketing or sumps to prevent rainwater from bypassing the drains to a lower elevation.

6.5 Influence of Vertical and Sloped Surfaces

6.5.1 The Designer shall take into account the water volume contributed by sloped and vertical surfaces adjacent to each drain as dictated in the applicable code.

6.5.2 The effective catchment area of a vertical surface shall be calculated as defined by the applicable code.

6.5.3 In the absence of a requirement for calculating flow from a vertical surface in the code, the Designer shall use the following method:

6.5.3.1 The effective catchment area of a single wall shall be 50% of its total vertical surface area.

6.5.3.2 Where two or more walls form an angle or bay, the direction of the wind should be considered.

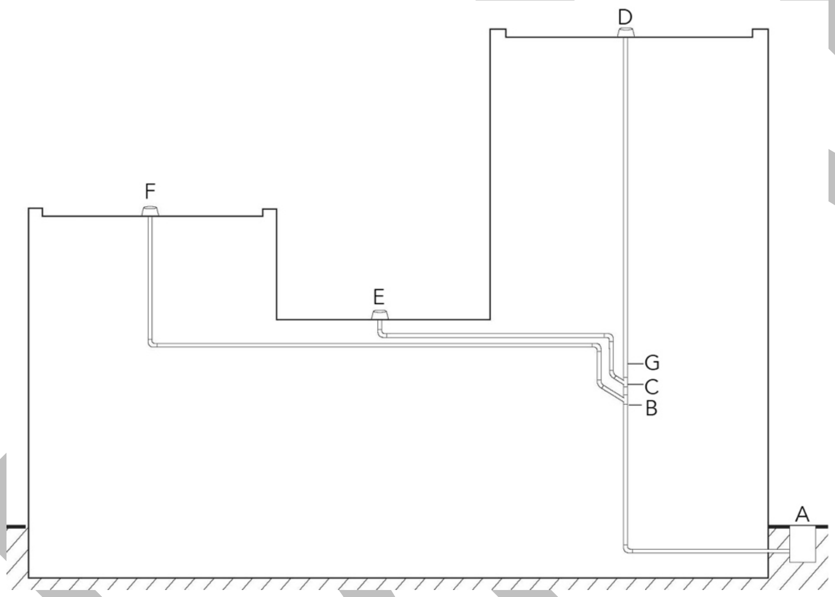
6.5.3.3 The calculated area of contribution for sloped surfaces shall be determined by adding the horizontal surface area to 50% of the change in elevation.

6.6 Influence of Varying Surface Type, Elevation, and Potential Flow

6.6.1 Although it is possible to tie several siphonic roof drains (even at differing elevations) together for routing to a common stack, certain considerations for varying roof surface elevations, types, flow rates, and positions shall be taken into account by the Designer.

6.6.2 A building may have roof surfaces at different levels and/or with different roofing surfaces. Roofs or parts of roofs can be sheltered from rainfall under certain wind conditions and rainfall angles of descent. On roofs with differing roofing materials, the rate of rainwater flow to the roof drains might vary. An example is the drainage of a single-ply membrane roof and a gravel-ballasted roof to one stack system. Roofs with different roofing surface type run-off rates shall be drained using separate siphonic systems.

Figure 6.1: Drainage of Roofs at Different Levels



6.6.3 If it is possible for parts of a building's roof surface to be totally or partially sheltered from rainfall (e.g., drain E in Figure 6.1), a specific dimensioning procedure as per sections 6.6.3.1 to 6.6.3.5 shall be applied.

6.6.3.1 In Figure 6.1, three different roof levels are drained by three drains (or sets of drains). Unless the designer has determined that the roof areas and the difference in elevations will not significantly disrupt the flows, the three drain sets shall not be connected at point G since drains at location E may be sheltered from rainfall by the higher roofs on either side and therefore contribute no water and create a point of air infiltration. Each drain set from D, E, and F shall have separate stacks prior to connection to a common stack for discharge to point A.

6.6.3.2 Tie-in locations B and C on the stack system shall be regions of zero to positive pressure. However, the head pressures at locations B and C shall not be greater than the vertical difference between them and the lowest connected roof elevation (roof elevation at E).

6.6.3.3 Pipe Sections D-C, E-C, and F-B shall be dimensioned for their respective catchment areas and elevations including any vertical wall surfaces and/or sloped surfaces assuming full-bore flow.

6.6.3.4 Section A-B shall be dimensioned for the total flow from drain sets D, E, and F and for the vertical difference between A and B. Section B-C shall be dimensioned for the total flow from drain sets D and E.

6.6.3.5 With this dimensioning procedure, varying elevations, roof surface types, flow rates, and rainfall sheltering are not relevant. If drain set E were to be sheltered from rain, for example, roofs D and F will continue to operate siphonically without air being ingested through drains at E.

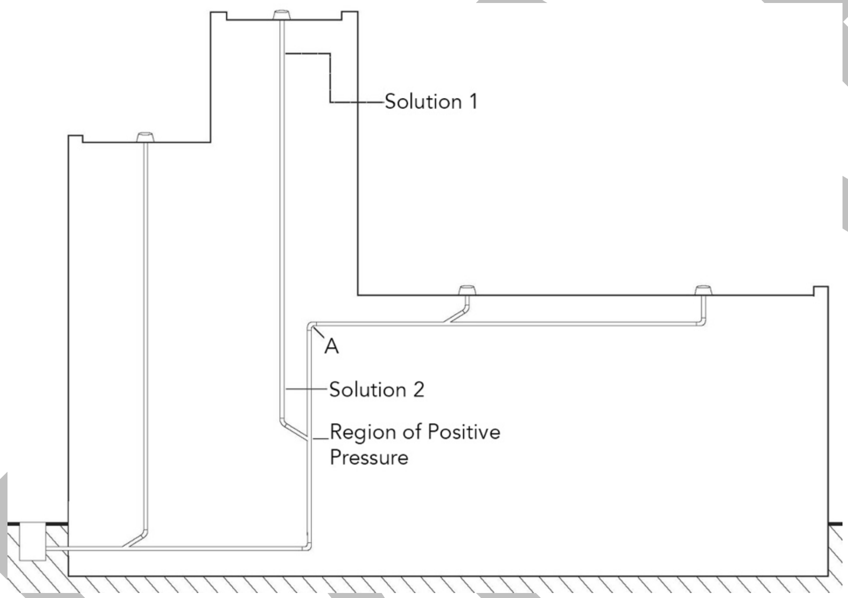
6.6.4 Systems shall be analyzed using flow rates to individual drains with and without ~~contributions from~~contributing factors that could influence flow. ~~such~~ Such ~~as contributions~~contributing factors are from wind~~-~~blown rain and~~/or~~ flows to secondary systems ~~for~~ when the adjacent primary drain ~~to be~~is blocked~~ or not~~. When the low flow condition varies significantly from the design condition, the system shall not be connected to dissimilar systems. See section 6.6.1.

6.7 Penthouse Roofs

6.7.1 The drainage of a penthouse roof is a situation similar to that described in Section 6.6.3.

6.7.2 Figure 6.2 below shows two options available for draining the higher penthouse roof along with the general roof surface.

Figure 6.2: Penthouse Drainage Options



6.7.3 In the case of Solution 1, the catchment area of the penthouse shall be included in the assignment of flows to the respective drains below receiving the water.

6.7.4 The penthouse drain shall not be tied into a region of negative pressure as in location A.

6.7.5 In Solution 2, the stack of the penthouse drain(s) shall be tied into a region of zero to positive pressure.

7.0 PIPEWORK DIMENSIONING

7.1 General

7.1.1 Siphonic theory is described in Section 4. The basis of the Designer’s selection of the design rainfall intensity (I_d) is outlined in Section 5.

7.1.2 The purpose of this section is to describe how the given equations and design rainfall intensity are applied to dimension a piping system to achieve the full-bore flow necessary for intended siphonic drain performance.

7.1.3 Several roof drains will normally be needed to drain a roof. The building’s siphonic system may consist of several stacks and points of discharge. In this section, the procedures described apply to a single stack system with more than one drain tying into it.

7.2 Sections and Section Parts

7.2.1 The pipework path between a single roof drain and the point of discharge comprises a single siphonic piping section. Equation 4.6 is applied to one section.

7.2.2 Roofs are commonly drained by multiple drains. A single point of discharge with more than one connected drain will have a number of sections that must be evaluated.

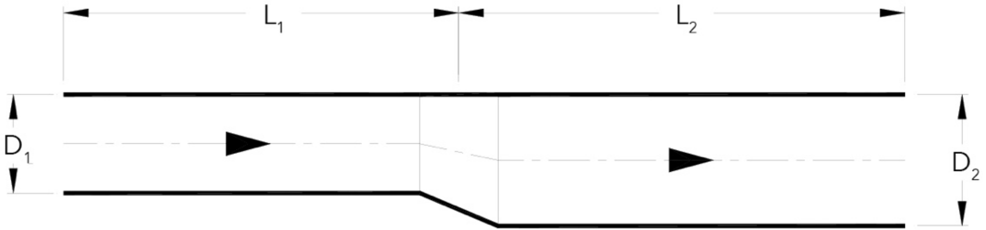
7.2.3 A section part is an individual component of the pipework system such as a pipe length with fittings or roof drain with a constant volumetric flow rate, velocity, and inner diameter. Since multiple drains typically tie into a single point of discharge, individual sections will normally share common section parts.

7.3 Lengths of Section Parts

7.3.1 Section parts arrange in series along a particular section and are connected with a fitting such as a coupling, reducer, or lateral. Since these fittings have actual dimension, a standard method of measuring the length of section parts shall be followed.

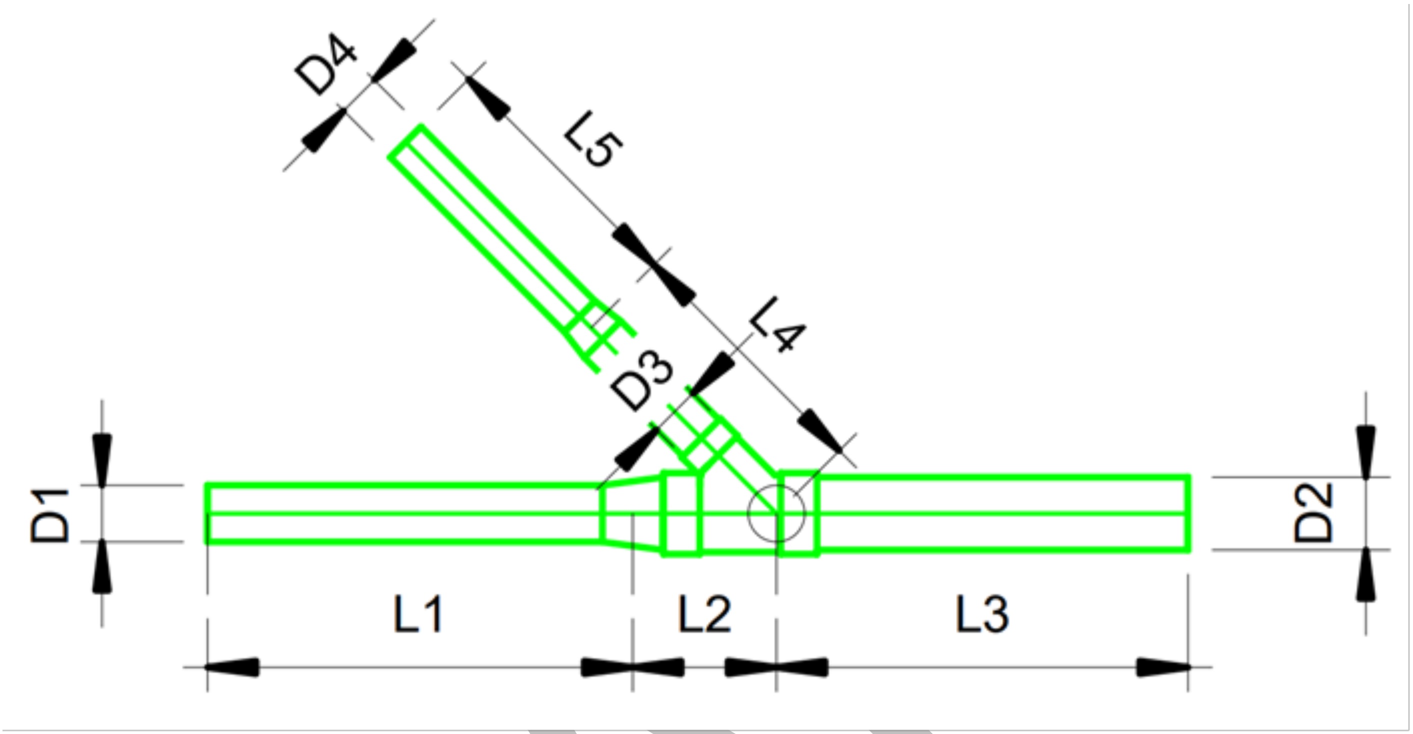
7.3.2 Where there is an increase in pipe diameter, the dimensions of the upstream and downstream section parts shall be referenced to the mid-point of the coupling or reducer fitting as shown in Figure 7.1 below:

Figure 7.1: Increase in Pipe Diameter (Side View)



7.3.3 Where there is a merger of two water streams at a junction, several section parts may exist that shall be accounted for in hydraulic energy loss calculations. Figure 7.2 is an example of a junction where there are changes in diameter.

Figure 7.2: Typical Junction (View from Top)



7.3.4 In Figure 7.2, the upstream leg with diameter D1 has a length L1 referenced to the mid-point of the increaser of the lateral fitting's leg in accordance with Section 8.3.2. The lateral's leg with diameter D2 comprises a section part with length L2. The length is referenced to the intersection of the leg and branch centerlines. The lateral's branch of diameter D3 is a section part of length L4. The downstream leg of diameter D2 has length L3 as indicated.

7.4 Assigning Flows to Drains

7.4.1 When drains have been positioned, the Designer shall determine the total tributary area covered by each drain.

7.4.2 Systems should be designed so that roof drains from different roof types with different runoff coefficients are kept on separate piping systems.

7.4.3 The flow to each drain shall be determined by the following relationships:

Equation 7.1a (SI Units)

$$q_i = \frac{1}{3,600} C I_d A_i$$

Equation 7.1b (U.S. Customary Units)

$$q_i = \frac{1}{43,200} C I_d A_i$$

7.4.3.1 Where q_i is the flow in l/s (cfs) to drain area i with area A_i, in square meters (feet), at the design rainfall intensity I_d in mm/hr (in./hr).

The coefficient, C, is the expected runoff factor typically used by civil engineers and is a function of the roof surface's ability to convey water. For typical single-ply membrane roofs or sloped metal decks, a value of C = 1.0 shall be used.

7.4.3.2 In the case of green roofs or similar roof systems, consult with the roof system designer and the authority having jurisdiction, noting that the retention properties are greatly reduced when green roofs are saturated or very dry.

7.4.4 The Designer shall verify if the flows assigned to each drain are within the drain's flow range. The maximum flow of a given drain design shall not be exceeded. Refer to the manufacturer's published performance curves.

7.4.5 The Designer shall evaluate the depth of rainwater around the roof drain during siphonic flow conditions and coordinate this depth with the roof deck loading capacity and the height of secondary overflow drains or scuppers.

7.4.6 Refer to Section 6 to account for the influence of sloped surfaces and vertical walls on the flow of water to each drain.

7.5 Residual Head

7.5.1 An ideal siphonic system dimensioned according to Equation 4.6 will have a total calculated energy loss through the piping system precisely equal to the disposable head.

7.5.2 This condition corresponds to a residual head (h_r) = 0. This condition would ideally be repeated for every section in the siphonic system.

7.5.3 In real practice, the Designer will not be able to calculate an exact balance that Equation 4.6 calls for in every section. This is due to the following:

7.5.3.1 Pipe is available only in discreet nominal diameters.

7.5.3.2 The Designer does not have full freedom on the types and placement of fittings.

7.5.3.3 The number of required iterations to the energy loss calculations would be excessive and unreasonable to achieve perfect balance.

7.5.3.4 Random and transient air entrainment, which is normal in an operating siphonic roof drainage system, may cause flow to vary slightly.

7.5.4 Minor residual heads are acceptable. The residual head for a section can be expressed as follows:

Equation 7.2

$$h_r = Z_i - Z_e - \left[\sum_{j=1}^{m} (h_f)_j + \sum_{k=1}^{n+1} (h_t)_k \right]$$

7.5.4.1 Where h_r is the residual head, in feet, of a section.

7.5.4.2 A positive residual head corresponds to a pipe section with slightly more capacity than the selected I_d.

7.5.4.3 A negative residual head corresponds to a pipe section that is slightly undersized. In this case, the pipe system shall be re-dimensioned to bring $h_r \geq 0$.

7.5.4.4 A relatively large residual head in any section may result in a pipe flow pattern in the wavy stage and will not function in siphonic mode at the selected I_d. It will only function in a conventional gravity mode at a significantly reduced drainage capacity. The system must be resized to achieve a small but positive residual head. A residual head less than 1.0m (3.3 ft) of water column is generally acceptable.

7.6 Imbalance

7.6.1 The overall imbalance in a siphonic system is defined as the difference between the maximum and minimum residual head between sections (i.e., drains) tied to a common stack. Imbalance is expressed as follows:

Equation 7.3

$$h_i = [h_r]_{max} - [h_r]_{min}$$

7.6.2 The Imbalance, h_i, in a system shall not exceed 0.46 m (1.5 ft) or 10% of the disposable head, whichever is less.

7.6.3 Unless the designer has calculated the flow between drains, the system shall be balanced as indicated in section 7.6.2 using flows as indicated in section 7.4.

7.7 Variables Manipulated

7.7.1 When dimensioning a pipework system (i.e., configuring the section parts for a set of sections), the Designer can manipulate the following to achieve an acceptable residual head, imbalance, and minimum pressure.

7.7.2 Drain size or model (to change the drain resistance value).

7.7.3 The pipe diameter of a drain tailpiece other section part. The resistance of a section part varies inversely with the fifth power of pipe inner diameter. Thus, changes in one nominal pipe size can result in significant changes in head loss and residual head.

7.7.4 The length of a drain tailpiece.

7.7.4.1 The resistance of a section part varies directly with pipe length. Thus, pipe length variation has a less effect on residual head than diameter variation, but it can provide fine tuning to the system.

7.7.5 The diameter of the stack,

7.7.5.1 In general, a reduction in stack diameter is desirable to induce early plug flow in the pipe bore and expedite the priming process.

7.7.5.2 An oversized stack may never achieve plug flow and operate primarily with water adhering to the pipe inner surface in a gravity mode. This may delay or prevent system priming action.

7.7.5.3 The entire stack or the lower part of it should preferably have a smaller diameter than the horizontal main above.

7.7.5.4 In fully primed flow (i.e., full-bore flow), the velocity in the stack shall be greater than 2.2 m/s (7.2 ft/s) for stacks 150 mm (6 in.) and smaller. For pipes larger than 150 mm (6 in.), refer to appropriate testing data from drain manufacturers. Minimum velocity is a function of pipe diameter.

7.7.6 The assigned flows to adjacent drains,

7.7.6.1 This option is possible only if there is free communication of water between drains in a system.

7.7.6.2 The resistance in a section part increases directly with the square of volumetric flow. Thus, it is an effective method of managing system residual heads and imbalance.

7.7.7 There are virtually limitless options in managing residual head and imbalance by combining any of the above variables during system design to achieve acceptable imbalance, residual head, and minimum pressure.

7.8 Minimum Pressure

7.8.1 When a siphonic system primes, sections of the system experience a depressurization. Pressure gradually decreases from the upstream drain to the top of the stack section part due to irreversible energy losses induced by flow (friction).

7.8.1.1 Other parts of the system may experience a significant positive pressure, especially in the lower portions of piping in high-rise buildings.

7.8.2 If water reaches a low enough pressure at a given temperature, vapor bubbles develop and cavitation occurs.

7.8.3 The process of creation and then implosion of vapor bubbles may result in pipe vibration, disturbing noise, and other effects that may impact the integrity of the piping, hangers, and joints.

7.8.4 Another consequence of cavitation is a significant reduction in drainage capacity due to the expansion of water vapor into the piping system.

7.8.5 At a specified water temperature, the following condition shall be met at all points in the system under siphonic flow using Equation 7.4:

Equation 7.4

$$\frac{P_i}{\rho g} + (Z_i - Z_x) - \frac{V_x^{2}}{2g} \underset{[}{-} \sum_{j=1}^{m} (h_f)_j + \sum_{k=1}^{n} (h_t)_k = \frac{P_x}{\rho g} > h_{vp}$$

7.8.5.1 Where the subscript $_i$ is the inlet condition at the roof and $_x$ is an arbitrary point along the section being evaluated.

7.8.5.2 The static pressure (P_x) at every point in the section shall be greater than the vapor pressure of water (h_{vp}) at the operating temperature and atmospheric pressure.

7.8.5.3 The Designer shall take into account that atmospheric pressure during design rainfall intensity (I_d) will typically be lower than standard atmospheric due to the low pressure generating the storm event. Refer to Appendix A.

7.8.5.4 When evaluating minimum system pressure, base the system flow on the maximum (theoretical) disposable head available to the system. This may be greater than the available disposable head used to evaluate minimum system flow capacity with an assumed storm sewer surcharge condition. Refer to Section 4.7 “Disposable Head.”

7.8.6 Once cavitation has been established in a system, it may persist at a higher static pressure than that required to initiate it.

7.8.7 In practice, the minimum allowable static pressure for an installation shall not be lower than 90% atmospheric. Operating pressures below this level are at risk of initiating cavitation due to lowered atmospheric pressure of a storm system.

7.8.7.1 At sea level, static pressure shall not be less than 9.0 m (29.5 feet) of water column below atmospheric 1.07 m w.c. (3.5 ft) absolute.

7.8.7.2 Refer to Appendix A for further guidance.

7.8.8 In general, the top of the stack is the point of minimum static pressure in a system; however, sudden changes in velocity or elevation may cause a sufficient local drop in static pressure to initiate cavitation. Therefore, the Designer shall examine all points of the system to ensure sufficient static pressures will exist during operation.

7.8.9 The Designer shall also verify the minimum internal pressure rating of the pipe material, fittings, and joints used in the system.

7.8.9.1 If the pipe wall thickness is not sufficient to withstand an exterior pressure of 0.10 MPa (14.7 psia), pipe collapse will probably occur.

7.8.9.2 Pipe collapse will result in stoppage of system flow and may cause pipe wall failure and the ingress of water into the building.

7.8.9.3 Verify the maximum exterior pressure (i.e., minimum interior pressure) rating with the pipe manufacturer or the appropriate ASTM standards.

7.8.9.4 Note that the maximum exterior pressure rating of a pipe is significantly less than its maximum positive (interior) pressure rating. This is due to the fact that the pipe wall structure is less stable under negative pressure (i.e., exterior compression).

7.8.9.5 Some mechanical pipe joints utilizing elastomer gaskets may not seat properly when subject to negative internal pressure. Refer to manufacturer data for the selection of gaskets rated for negative pressure applications.

7.8.9.6 Refer to manufacturer data for expansion joint pressure ratings. Mechanical expansion joints used in pump suction applications are generally rated for negative internal pressures.

7.8.9.7 Refer to Appendix A for atmospheric pressures and water vapor pressures.

7.9 Minimum Velocity

7.9.1 Sufficient velocity in the pipe system is necessary to ensure that any debris entering the system is suspended and carried easily through the piping without depositing and causing eventual blockages.

7.9.2 Sufficient velocity is also required to provide adequate air-water mixing in the piping to facilitate the priming process.

7.9.3 Minimum velocity in the tailpiece and all horizontal ~~and tailpiece~~ piping ~~sections~~ shall be 0.9144 m/s (3 ft/s).

7.9.4 Refer to stack design practices for the acceptable minimum velocity to achieve system priming.

7.10 Tailpiece Design

7.10.1 Siphonic roof drainage systems must be capable of starting the priming phase almost immediately. Proper tailpiece design provides accelerated priming action.

7.10.2 When rainfall occurs, the tailpiece section parts are normally the first to achieve full-bore flow while the main collection piping fills. Therefore, tailpiece design shall not inhibit air-to-water mixing.

7.10.3 The nominal diameter of the connecting tailpiece shall be equal to or less than the drain's outlet nominal diameter unless shown by experiment by the drain manufacturer that a larger size is permitted. An oversized tailpiece connection to a drain may delay or prevent system priming action.

7.10.4 In general, use increasers only in the horizontal orientation to transition to a larger pipe diameter. Use reducers only in the vertical orientation to transition to a smaller pipe diameter.

7.10.5 The use of flexible hoses in the tailpiece is prohibited.

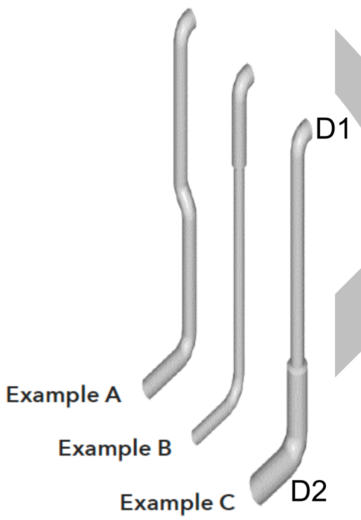
7.11 Stack Design

7.11.1 Siphonic roof drainage systems must be capable of starting the priming phase almost immediately. Proper stack design provides accelerated priming action.

7.11.2 Stack design shall prevent the air within the stack from becoming trapped by allowing for proper air-to-water mixing within the stack. The flow pattern in the stack can be described as a plug flow, where pockets of air are trapped and thusly dragged down between two successive slugs of water until the majority of the air is purged. Then a bubble flow will develop until the full-bore state is achieved.

7.11.3 The diameter of the stack shall not be larger than the diameter of the connected horizontal main collection piping (i.e., d1 ≥ d2 is required). See Figure 7.3 (a).

Figure 7.3: Design of Stacks



7.11.4 Stacks should not be dimensioned with an upper section part connecting to a lower section part of greater diameter (as shown in Figure 7.3 (c)) unless the Designer intends to end the siphonic action at that point of the stack. Such a design limits the disposable head to the height of the upper, smaller diameter pipe section with consequently reduced drainage capacity.

7.11.5 When the diameter of the stack must be equal to the connected horizontal main collection piping and the stack velocity is marginal, the stack may be offset as shown in Figure 7.3 (a) with two eighth bends. This offset triggers air-to-water mixing better than a straight vertical section alone.

7.11.6 In general, a reduced stack diameter as shown in Figure 7.3 (b) should be utilized whenever hydraulic calculations permit.

7.11.7 In general, continuing the stack diameter horizontally at the stack base for about 10 pipe diameters prior to increasing to another larger diameter pipe will expedite the priming process by promoting a hydraulic jump at the stack base. The design may incorporate an increase in diameter using a reducer immediately upstream of bend transitioning from vertical to horizontal.

7.12 System Priming Time

7.12.1 Siphonic systems should be designed to prime quickly and attain the design flow rate within the duration of the design storm event.

7.12.2 Priming should occur quickly to minimize ponding and avoid overloading the roof.

7.12.3 Priming depends on many independent factors and there is no universally accepted method for accurately predicting the priming time. The priming time can be estimated using Equation 7.5.

Equation 7.5

$$T_F = \frac{1.2\ V_P}{Q_{in}}$$

Equation 7.6

$$Q_{in} = \Sigma\ Q_T$$

NOTE: The factor of 1.2 in Equation 7.5 allows for the time needed to produce full-bore flow conditions in the pipework.

7.12.4 Tailpipes should be designed to discharge into the collector pipe at a rate that is sufficient to produce negative pressures quickly within the system. Check the priming performance of each of the tailpipes, assuming it to be acting at the flow capacity, Q_T, independently of the rest of the system with the tailpipe operating siphonically but discharging at atmospheric pressure into its collector pipe.

7.12.5 The priming performance of the stack should be checked by adding together all of the values of Q_T to obtain the total initial flow rate, Q_{in}, entering the collector pipe(s). Using the volume of the piping, V_P, the filling time, T_F, of the siphonic system can then be estimated with Equation 7.5.

8.0 ENGINEERING CONSIDERATIONS FOR THERMOPLASTIC PIPE

8.1 General

8.1.1 Plastic piping utilized for siphonic roof drainage systems experiences physical forces and conditions not otherwise encountered in conventional (i.e., atmospheric) roof drainage systems. Internal pipe pressure may be as low as minus 9.0 m w.c (29.5 ft w.c.) and may be as high as 5 bar or more. Hydrostatic pressure test methods for pipe, fittings, and other components are provided by ASTM D1599. Negative pressure limitations are provided in this standard.

8.1.2 The flow rates and velocities attained in siphonic roof drainage systems may be up to 10 times higher than those encountered in atmospheric DWV systems. Thus, the resultant forces exerted on the piping system must be accommodated by the pipe, fitting, and joint material and not exceeded by the designer or installer.

8.2 Material Properties of Thermoplastic Pipe

8.2.1 In evaluating the limiting or maximum pressures, forces, and deflections on plastic pipe, fittings, and components covered by this standard, the following material properties listed in Table 8.1 are assumed at an operating temperature of 20°C (68°F).

8.2.2 Creep modulus varies by plastic material, temperature, age, and time of loading (T_l). The time of loading is defined as the period of time a plastic siphonic piping system is expected to be operating at the relevant pressure. Once the storm event is over and the system drains, the material recovers and assumes its original tensile modulus (i.e., $E_c(T_l = 0) = E_t$). However, the material elastic modulus and creep modulus also typically decrease with age. Refer to pipe manufacturer data for the appropriate creep modulus value.

Table 8.1: Material Properties at an Operating Temperature of 20°C (68°F)

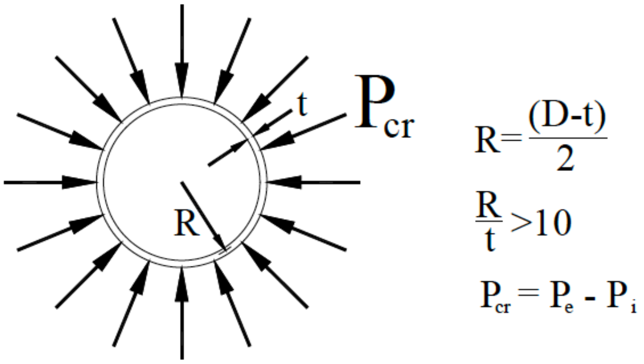
Property/ Material	Tensile Modulus of Elasticity	Creep Modulus	Poisson's Ratio	Rate of Thermal Expansion
Symbol	E_t	E_c	μ	C_{tx}
Units	MPa (psi)	MPa (psi)	dimensionless	cm/cm/°C (ft/ft/°F)
ABS	2206 (320,000)	Varies. Refer to 8.2.2.	0.35	10.3 E-5 (5.7 E-5)
HDPE	862 (125,000)		0.45	18.0 E-5 (10.0 E-5)
PVC	2827 (410,000)		0.35	5.2 E-5 (3.0 E-5)
Test Method	ASTM D638	ISO 899	ASTM E132	ASTM D696

8.3 Allowable Pressure

8.3.1 Positive Internal Pressure: The positive pressure ratings (i.e., hydrostatic burst pressures) for plastic pipe and fittings are generally provided by the respective pipe material specification (e.g., D 2665 for DWV PVC). The calculated internal pressures in a siphonic roof drainage system shall not exceed the rated hydrostatic pressure of the specified pipe material or fitting. When pressures are exceeded, another suitable pipe material and joint system must be specified.

8.3.2 Negative Internal Pressure: Maximum positive internal pressure does not relate to maximum external pressure (i.e., negative pressure). The application of external pressure on a pipe wall may result in a structural failure due to a less stable physical geometry and variations in manufacturing at stresses much lower than the material's tested elastic limit. Figure 8.1 represents the geometry and the forces acting on the pipe wall.

Figure 8.1: External Loading of a Thin-Walled Cylindrical Shell



8.3.3 The minimum factor of safety (FS) used to evaluate the allowable pressure (P_{al}) for siphonic roof drainage piping shall be 3.0.

8.3.4 When calculating allowable pressure (P_{al}), the creep modulus (Ec) of the material shall be used at the specified time of loading.

8.3.5 The wall thickness (t) shall be the minimum value listed in the respective specification taking into account the allowable negative tolerance in the manufacture of the pipe product.

8.3.6 Elastic modulus and creep modulus values for plastic pipe are influenced by time and temperature. For the purposes of this specification, the operational temperature range shall be not less than 4.4°C (40°F) and not more than 30°C (90°F). Thus, piping shall be assumed to be an "outside cold cylinder" as defined in the ASME Boiler and Pressure Vessel Code.

8.3.7 The allowable pressure (P_{al}) for a pipe of a given length, diameter, and pipe wall thickness shall not be less than 1.0 bar (14.7 psia). In other words, a pipe segment within a siphonic pipe system shall be capable of withstanding full vacuum internally times the factor of safety without potential for collapse.

8.3.8 When the standard wall thickness specified in the respective ASTM specification is unable to sustain structural integrity at the allowable pressure, a thicker pipe wall meeting the allowable pressure shall be used.

8.3.9 Calculation of allowable pressure (P_{al}): The minimum required pipe wall thickness (t) shall be based on Equations 8.1 and 8.2 in Table 8.2 and the mechanical and dimensional properties of the pipe material evaluated. Equations 8.1 and 8.2 apply for a long cylindrical tube of length L and wall thickness t under uniform external pressure with (R/t) > 10.

Table 8.2: Pipe Wall Thickness Calculations	
Equation 8.1[1] When L ≥ 4.9R √R/t	Equation 8.2[2] When L < 4.9R √R/t
$P_{cr} = \frac{E_c}{4(1-\mu^2)} \left(\frac{t}{R}\right)^3$	$Pcr = 0.807 \left[\frac{E_c t^2}{LR}\right]\left[\left(\frac{1}{1-\mu^2}\right)\left(\frac{t}{R}\right)^2\right]^{0.25}$

1. Roark & Young, Roark's Formulas for Stress and Strain, 7th Edition, McGraw-Hill, New York, NY, 2002, Table 15.2, No. 19a, p. 736.
2. Roark & Young, Roark's Formulas for Stress and Strain, 7th Edition, McGraw-Hill, New York, NY, 2002, Table 15.2, No. 19b, p. 736.

8.3.9.1 The parameter E_c is the elastic creep modulus at the specified time of loading. The allowable pressure (P_{al}) shall be the calculated critical buckling pressure divided by the factor of safety (FS) as in Equation 8.3 below:

Equation 8.3

$$P_{al} = \frac{P_{cr}}{FS} \geq 1.0\ bar\ (14.7 psia)$$

8.4 Reactive Forces

8.4.1 Siphonic roof drainage systems are characterized by high velocity, full-bore flow. Plastic drainage pipe, fittings, and components installed in siphonic roof drainage systems shall be properly supported not only for horizontal support, but also for lateral or anchoring support at changes in direction.

8.4.2 Reactionary Force (Fr): The forces produced by the change in momentum of the water stream shall be determined based on Newton's Laws. In vector form, force is calculated from Equation 8.4. The parameter dm/dt represents mass flow rate in kilograms per second (slugs per second).

Equation 8.4

$$\vec{F} = \frac{dm}{dt}\vec{\Delta V}$$

8.5 Thermal Displacement

8.5.1 Change in pipe length due to variation in temperature shall be evaluated with Equation 8.5:

Equation 8.5

$$\Delta L = CtxL\Delta T$$

9.0 PIPEWORK DESIGN AND INSTALLATION DETAILS

9.1 Pipe Materials, Fittings, and Joints

9.1.1 The design calculations prepared by the Designer are valid only for the specified pipe material, inner diameters, surface roughness, thermal expansion properties, and fittings. The installing contractor shall not substitute the specified pipe material, pipe sizes, or fittings with another without approval of the Designer and revised calculations.

9.2 Expansion and Contraction

9.2.1 Changes in system temperature are expected in siphonic roof drainage systems.

9.2.2 Thermal expansion and contraction shall be based on local temperature and building temperature extremes. This is particularly important for thermoplastic piping.

9.2.3 Other pipe relative movement shall be based on structural specifications for seismic and thermal movement of building elements.

9.2.4 Provide appropriate flexible elements in the piping system to relieve stress due to thermal, seismic, or other building movement.

9.3 Sway Bracing and Anchoring

9.3.1 The Designer shall evaluate the forces produced upon the piping due to changes in direction of fluid flow at steady state conditions.

9.3.2 Steady state reactionary thrust caused by changes in direction of fluid flow (i.e., change in momentum) is evaluated by the following equation:

Equation 9.1

$$\vec{F} = \rho Q \Delta \vec{V}$$

9.3.2.1 Where F is the force vector in Newtons (lbf), ρ is water density (997 kg/m^3 [1.94 slugs/ft^3]), Q is volumetric flow rate in m3/s (cfs), and ΔV is the change in velocity vector in m/s (ft/s).

9.3.3 Provide appropriate thrust restraints and anchors in the parts of the system experiencing these forces. Restraints and anchors may be attached to the pipe hanger only when the hanger is rigidly attached to the pipe.

9.3.4 Lateral restraints shall be installed every 9.0 m (30 ft) at each branch take-off and at each change in direction. Siphonic designs perform at higher velocities than conventional gravity systems. The designer must evaluate the system for lateral movement at each branch take off and change of direction.

9.3.5 Provide sway bracing or equivalent lateral supports to drain tailpiece sections as close to the drain connection as possible. Initial air and water (i.e., two-phase) flow in the drain tailpiece may induce vibration. This movement may disturb drain flashing or its fixing to the roof deck or gutter unless the tailpiece is secured. Note that an engineering analysis of these forces is not possible.

9.4 Pipe Support

9.4.1 Conventional roof drainage systems typically run to the closest structural column and drop underground and exit the building as buried pipe. In siphonic roof drainage systems, a significant length of piping might be run overhead, requiring support from the roof framing system or roof deck.

9.4.2 Coordinate piping sizes, distributed weight, and thrust loads with the structural engineer to verify adequate structural strength.

9.4.3 Support piping at intervals consistent with accepted industrial practice or with the governing plumbing code for piping full of water.

9.5 Cleanouts

9.5.1 The system's primary access for rodding shall be from the roof drains.

9.5.2 Cleanout fittings creating an air pocket or a discontinuity in pipe flow should be avoided wherever possible.

9.5.3 If cleanouts are to be included, they should be designed as a removable spool piece or fitting by means of an approved mechanical coupling.

9.5.4 Cleanouts using a lateral wye fitting shall have a removable access plug that is rated for both positive and negative interior pressure.

9.5.5 Lateral wye fittings used in siphonic pipe systems shall be treated as an eighth miter bend fitting for the purposes of single resistance losses.

9.6 Eccentric Reducers

9.6.1 Siphonic roof drainage systems prime to full-bore flow by purging of air in the pipework through proper air-to-water mixing. The introduction of air pockets in the pipe system through increasers, cleanout connections, etc. could delay or prevent system priming.

9.6.2 When eccentric reducers are used, they shall be installed with the flat side oriented with the pipe crowns and the sloped side with the invert.

9.6.3 Eccentric reducers placed in the vertical just after an elbow turning down shall have the flat side oriented with the outside radius of the elbow.

9.7 Insulation

9.7.1 Siphonic roof drainage piping is typically installed in the air-conditioned interior of a building among the overhead roof structure.

9.7.2 If the temperature of the rainwater entering the system from the exterior weather should cause the temperature of the piping's outer surface and brackets and hardware in contact with it to drop below the dewpoint of the conditioned space, condensation will form on the pipe surface.

9.7.3 This sweating can cause water damage to interior elements of the building.

9.7.4 All interior horizontal piping and brackets and hardware in contact with it (not buried) shall be insulated with minimum 25 mm (1 in.) thickness glass fiber insulation with a vapor barrier and all-service jacket or as specified in the governing plumbing code. Insulation smoke and flame-spread characteristics shall comply with ASTM E84 testing requirements.

9.8 Heat Tracing

9.8.1 Where used, heat tracing shall be used only on the outside of the pipe and drain bodies.

9.8.2 Heat tracing may be substituted by providing minimal thermal insulation at the drain body location to allow internal heat loss to warm the drain body.

9.8.2.1 This method of drain body heating shall be evaluated by the Designer to ensure compliance with local building and energy code requirements.

9.9 Siphonic Roof Drainage Point of Discharge

9.9.1 When a siphonic roof drainage system is connected to an underground storm sewer system, the siphonic action shall be broken before the system is connected to the main storm sewer system.

9.9.2 Siphonic roof drainage systems should tie into a vented manhole or sump structure with a grated cover with free area of at least twice the cross-sectional area of the siphonic discharge pipe. This may be accomplished by substituting a standard manhole cover with a catch basin grate. Where a catch basin grate or other vented cover is not possible (e.g., the manhole is inside a building and must be sealed tight against possible overflow), a vent pipe of a minimum diameter equivalent to the siphonic discharge pipe may be extended from the manhole structure and terminate in an area approved by the governing plumbing code. While these conditions are recommended, other discharge conditions may be accommodated. If the siphonic roof drainage system ties into a non-vented manhole or pipe, the effects of pressure conditions at the discharge should be evaluated.

9.9.3 Flare out the discharge piping 10 or more pipe diameters prior to the vented manhole or sump. The resulting pipe diameter should be sufficient to return the system to open channel flow.

9.9.4 For other discharge conditions, consult the designer of the downstream storm drain system and the authority having jurisdiction

10.0 DRAWINGS, CALCULATIONS, AND SPECIFICATIONS

10.1 General

10.1.1 Refer to non-mandatory Appendix B for information on suggested means of determining the qualifications of Designers.

10.1.2 The drawings and specifications shall provide sufficient detail to the installing contractor to establish the required pipe cut lengths and install the required fittings in order to accurately conform to the Designer’s calculations.

10.1.3 The drawings and specifications shall clearly indicate that the siphonic roof drainage system is an engineered system meeting the rainfall intensity required by the governing building and plumbing codes.

10.2 Calculations

10.2.1 Hydraulic calculations shall be performed by the Designer to establish the engineered pipe sizing and configuration. The use of design software for siphonic roof drainage systems is highly recommended as it has become the prevailing standard of care in the industry. However, acceptable alternate methods can be used.

10.2.2 Calculations shall establish:

10.2.2.1 Design rainfall intensity in mm/hr (in./hr),

10.2.2.2 Pipe material (list ASTM standard),

10.2.2.3 Pipe surface roughness in meters (feet or mil),

10.2.2.4 Disposable head in m (ft),

10.2.2.5 Identification tag for each drain (i.e., section) corresponding to the drawings,

10.2.2.6 Flow to each drain in l/s (gpm or cfs),

10.2.2.7 Drain, including drain outlet diameter,

10.2.2.8 Elbow, including degrees of bend (e.g., 45 degrees),

10.2.2.9 Branch or junction, including branch angle (e.g., 45 degrees),

10.2.2.10 Leg,

10.2.2.11 Discharge,

10.2.2.12 Inner diameter for each section part in mm (in.),

10.2.2.13 Length of each section part in m (ft),

10.2.2.14 Flow within each section part in l/s (gpm or cfs),

10.2.2.15 Velocity in each section part in m/s (ft/s),

10.2.2.16 Velocity head in each section part in m w.c (ft w.c.),

10.2.2.17 Energy loss through each section part in m w.c (ft w.c.),

10.2.2.18 Change in elevation from inlet to drain of each section part in m (ft),

10.2.2.19 Static pressure head at both ends of each section part in m w.c. (ft w.c.),

10.2.2.20 Residual head for each section (drain) in m (ft), and

10.2.2.21 Overall imbalance between sections (drains) in m (ft).

10.3 Specifications

10.3.1 Specifications shall include a complete description of the siphonic roof drainage piping material including fittings and joining method(s).

10.3.2 Pipe materials shall include ASTM standard and wall class (thickness).

10.3.3 List fitting and joint ASTM standards and include joint pressure ratings for both positive and negative pressure limits.

10.4 Plans

10.4.1 Pipe elevations shall be noted on each pipe section referenced to the top of pipe (T.O.P.) or pipe centerline and the project zero datum. The Designer shall coordinate all piping with all trades

10.5 Details

10.5.1 The Designer shall provide sufficient detail on the drawings to instruct the installer on the size, orientation, and support of the piping, fittings, and drains.

10.5.2 A drain fastening and flashing detail should be included on the drawings.

10.6 Isometrics

10.6.1 Prepare isometric diagrams of the system.

10.6.2 Isometrics shall show the full length of the piping system and portray changes and direction and elevation.

10.6.3 Include water direction of flow and the flow rates used to perform hydraulic calculations.

10.6.4 Include roof area covered by each drain and the total area covered by the piping system.

11.0 INSTALLATION

11.1 General

11.1.1 The purpose of this section is to provide guidelines to installers of siphonic roof drainage systems.

11.1.2 Siphonic roof drainage systems are piping systems like any other and shall be installed in accordance with accepted industry practice, governing codes and regulations, and material manufacturers' written instructions. Also, the Designer's specifications and details for lateral supports and sway bracing shall be followed.

11.1.3 Siphonic roof drainage systems are engineered. Their performance is directly related to pipe material, pipe diameters, pipe lengths, pipe elevations, and the placement of fittings. These systems can be altered to suit necessary construction modifications or unforeseen conflicts, but such alterations shall be reviewed and verified by the Designer.

11.1.4 Do not make piping alterations without the approval of the Designer.

11.2 Proposing Changes

11.2.1 Although a siphonic roof drainage system is engineered by a Designer, the provided design is only one of many possible configurations. Designs are highly flexible and can accommodate moderate changes to account for conflicts and other unforeseen conditions.

11.2.2 Installers may propose changes to the Designer. Provide proposed changes to the Designer in writing and include the following:

11.2.2.1 The affected stack. If not identified uniquely by the Designer's drawings, indicate building grid location as a reference.

11.2.2.2 Pipe alterations sought. Draw in plan and elevation views (or isometric view) of the revised pipe configuration including pipe diameter, fittings, approximate lengths, and surrounding obstructions. Legible hand drawings are acceptable.

11.2.2.3 What, if any, piping has already been installed.

11.2.3 The Designer shall incorporate the proposed changes into the engineering calculations. The Designer shall determine if the changes are acceptable. If not, the Designer shall provide an alternative solution to meet the installation requirements and respond in writing. Some changes may require other adjustments to the piping either upstream or downstream to maintain acceptable performance parameters.

11.3 Construction Tolerances

11.3.1 Piping 100 mm (4 in.) and smaller shall be fabricated to be within ±100 mm (4 in.) of the length specified on the Designer's drawings.

11.3.2 Piping larger than 100 mm (4 in.) shall be fabricated to be within ±200 mm (8 in.) of the length specified on the Designer's drawings.

11.4 Setting of Drains

11.4.1 Drains in gutters shall be set level to one another within a construction tolerance of ± 10.0 mm (3/8 in.)

11.4.2 Leveling shall be accomplished by means of suitable surveying equipment capable of measuring to the tolerances specified.

11.4.3 Drains that do not share a common valley, gutter, or other tributary area are not required to be level to one another per section 11.4.1. Install drains within accepted construction tolerances.

11.5 Pipe and Drain Protection During Installation

11.5.1 When not actively used for roof drainage during construction:

11.5.1.1 Cover each drain, and

11.5.1.2 Remove baffle and leaf guard to prevent construction damage and store according to the manufacturer's specifications.

11.5.2 Siphonic roof drains and the siphonic piping system shall not be used as temporary drainage during construction without the consent of the Designer.

11.5.2.1 Protect pipe ends from ingestion of construction debris by covering with tape or other suitable means.

11.5.2.2 Siphonic drains used as temporary drainage shall be piped separately out the side of the building until their final connection to the siphonic piping system.

11.5.2.3 Under no conditions shall the siphonic drains and permanent piping be used to drain a roof deck having a poured concrete slab. Cement dust and other residuals ingested by the piping may harden and cause permanent blockage of the piping. Protect drains and piping by covering the drain body by bolting a plywood disk or other suitable cover to the body flashing clamp bolts. When the final membrane roofing material is laid down, the drains may be uncovered to attach the flashing ring and cut the membrane opening. The drain and piping may then be used for active roof drainage.

12.0 INSPECTION AND TESTING

12.1 General

12.1.1 Siphonic roof drainage systems shall be inspected and tested to ensure compliance with the drawings and specifications prepared by the Designer.

12.1.2 The Designer or designated inspector shall periodically inspect and observe the installation of a siphonic roof drainage system. All discrepancies shall be brought to the immediate attention of the plumbing contractor. All inspections shall be documented in writing and filed with the office of the ~~code official~~Authority H~~h~~aving J~~j~~urisdiction.

12.1.3 The Designer shall submit a final report in writing to the Authority Having Jurisdiction~~code official~~ upon completion of the installation to:

12.1.3.1 Certify that the siphonic system installation is in conformance with the approved construction documents,

12.1.3.2 Certify that the specified pipe material, fittings, and joints were installed, and

12.1.3.3 Certify that the requisite integrity testing has been completed.

12.1.4 The Authority Having Jurisdiction~~code official~~'s notice of approval for the installation shall not be issued until the Designer has issued the written certification.

12.1.5 The plumbing contractor shall follow any additional testing requirements of the Authority Having Jurisdiction~~inspecting official~~.

12.1.6 A complete flow test of a siphonic roof drain system is not required.

12.1.7 The siphonic roof drain system shall be inspected and tested to ensure compliance with the contract documents and for pipe integrity as described below.

12.2 Drains

12.2.1 Drains shall be securely fastened to the roof deck by means of the specified fastening assembly and the manufacturer's installation instructions.

12.2.2 Flashing clamps shall be in place, engaging the waterproofing membrane system and tightened down to the specified torque specifications provided by the drain manufacturer.

12.2.3 The drain baffle shall be in place and secured to the drain body in accordance with manufacturer instructions.

12.2.4 The drain baffle and body shall be free of debris.

12.2.5 The complete drain assembly shall be in place, and the assembly shall comply with ASME A112.6.9.

12.3 Tailpieces

12.3.1 The tailpiece assembly shall be properly supported to prevent stress on piping, pipe joints, drains, and drain joints.

12.3.2 The tailpiece assembly shall be properly restrained laterally to prevent movement of the piping and drain body with respect to the roof deck.

12.3.3 Unrestrained movement of the drain body may result in the deterioration of the waterproofing system around the drain and cause leakage.

12.3.4 The pipe diameters, pipe lengths, reducers, and fittings of the tailpiece sections shall be as shown on the contract documents.

12.3.5 Prior to final connection of the tailpiece to the drain, the plumbing contractor shall visually inspect the tailpiece to verify that all tailpieces are free of debris or other obstruction.

12.4 Main Collection Piping

12.4.1 Main collection piping shall be properly supported to prevent stress on piping and pipe joints.

12.4.2 Pipe lateral bracing and anchoring shall be installed as shown on the contract documents.

12.4.3 Pipe expansion joints shall be installed as shown on the contract documents.

12.4.4 Increaser/reducer fittings should be of the eccentric design, when possible.

12.4.5 Eccentric reducers shall be installed with the level edge at the pipe crown and the sloped edge at the pipe invert.

12.4.6 All fittings shall be installed at the locations as shown on the construction documents.

12.4.7 Pipe diameters of main collection piping shall be as shown on construction documents.

12.5 Stacks

12.5.1 Stack sections shall be properly supported and restrained.

12.5.2 Stack pipe diameters shall be exactly as shown on the construction documents.

12.5.3 Stacks reducing in diameter at top of the stack may use eccentric reducers placed in the vertical just after an elbow turning down and shall have the flat side oriented with the outside radius of the elbow.

12.5.4 Other than at the top of the stack, reducers in the stack should be of concentric design.

12.6 Pressure Testing, Positive

12.6.1 All piping shall be pressure tested per local code and pipe manufacturer’s defined testing procedure.

13.0 MAINTENANCE

13.1 General

13.1.1 Like any other piping system within a building, siphonic roof drainage systems must be maintained properly to ensure reliable performance.

13.1.2 The primary concern for siphonic roof drainage systems (as is the case with conventional systems) is the accumulation of debris around the drain leaf guards that may partially blind or obstruct the drain.

13.2 Roof Surface

13.2.1 Roof surfaces shall be maintained clear of excessive debris such as leaves, bird nests, bird feathers, and pine needles.

13.2.2 Prior to turning over a siphonic roof drainage system to an owner, the contractor shall clear the roof of any construction debris such as gloves, tape, wrappers, plastic bags, etc.

13.2.3 The roof surface and drains should be inspected at least twice annually. Lower roof surfaces normally subject to accumulation of leaves, etc. should be inspected more frequently.

13.3 Drains

13.3.1 Drains must be checked periodically to ensure they are clear of debris.

13.3.2 Leaf guards, if used, shall be replaced when damaged or missing.

13.3.3 Baffles shall be replaced if damaged or missing.

13.3.4 The drains shall be examined periodically to ensure that no debris has accumulated in the drain body or tailpiece. Drains with excessive debris shall be rodded out.

14.0 CONTROLLED FLOW SYSTEMS

14.1 General

14.1.1 Conventional roof drainage systems are sometimes engineered to act as controlled flow systems to restrict the rate at which water flows from a roof or gutter to the storm sewer. Often this is a result of local restrictions on stormwater runoff where retention ponds or underground tanks are not practical.

14.1.2 Conventional controlled flow systems restrict flow at the drain by use of a roof drain product intended for this application. The excess water is normally retained on the roof until a point of overflow is reached.

14.1.3 Siphonic roof drainage systems can be thought of as inherently control flow. Since the piping system is designed to drain water from the roof at a specific rate, a control flow condition can be achieved by selecting a design rainfall intensity to the desired limit.

14.2 Roof Drains

14.2.1 Siphonic controlled flow systems utilize the exact same drain products described in Section 5. No special drains or adapters are required.

14.3 Overflow

14.3.1 The roof deck shall always be protected against excessive water accumulation by providing an independent overflow system.

14.3.2 Refer to the governing building and plumbing codes for these design requirements.

14.3.3 Confirm with the structural engineer the maximum roof static load in kg per square meter (pounds per square foot) and convert to equivalent mm (in.) of water.

APPENDIX A: WATER AND ATMOSPHERIC PROPERTIES REFERENCE (INFORMATIVE)

Table A.1: Properties of Water at Various Temperatures at Sea Level (SI Units)

Temp, (C)	hvp		Density, kg/m^2	Kinematic Viscosity, m^2/s
	atm	m w.c.		
0	0.006025	0.0623	999.82	1.79E-6
2	0.006966	0.0720	999.94	1.69E-6
4	0.008027	0.0829	1000.0	1.60E-6
8	0.01059	0.109	999.91	1.41E-6
10	0.01212	0.125	999.77	1.31E-6
14	0.01577	0.163	999.33	1.19E-6
16	0.01794	0.185	999.03	1.12E-6
18	0.02036	0.210	998.68	1.06E-6
20	0.02307	0.238	998.29	1.00E-6
22	0.02609	0.270	997.86	9.60E-7
25	0.03126	0.323	997.13	9.01E-7
28	0.03730	0.385	996.31	8.41E-7
30	0.04187	0.433	995.71	8.01E-7

Table A.1: Properties of Water at Various Temperatures at Sea Level (U.S. Customary Units)

Temp, (F)	hvp		Density, Lbm/ft^3	Kinematic Viscosity	
	psia	ft w.c.		centistokes	ft^2/s
32	0.08859	0.204	62.414	1.79	1.93E-5
35	0.09991	0.230	62.420	1.68	1.81E-5
40	0.12163	0.281	62.425	1.54	1.66E-5
45	0.14744	0.340	62.420	1.42	1.53E-5
50	0.17796	0.411	62.410	1.31	1.41E-5
55	0.21392	0.494	62.390	1.20	1.29E-5
60	0.25611	0.591	62.370	1.12	1.21E-5
66	0.31626	0.731	62.330	1.03	1.11E-5
68	0.33889	0.783	62.320	1.00	1.08E-5
70	0.36292	0.839	62.310	0.98	1.05E-5
75	0.42964	0.987	62.270	0.90	0.97E-5
80	0.50683	1.17	62.220	0.85	0.91E-5
85	0.59583	1.38	62.170	0.81	0.87E-5

Table A.2: Standard Atmospheric Pressures at Various Elevations (SI Units)

Elevation above sea level (m)	0	457	914	1,372	1,829	2,286
$P_a/\rho g$ (m w.c.)	10.4	9.81	9.28	8.78	8.30	7.84

Table A.2: Standard Atmospheric Pressures at Various Elevations (U.S. Customary Units)

Elevation above sea level (ft)	0	1,500	3,000	4,500	6,000	7,500
$P_a/\rho g$ (ft w.c.)	34.0	32.2	30.5	28.8	27.2	25.7

The values in Table A.2 are for standard atmospheric conditions. When evaluating acceptable minimum pressures in a siphonic piping system, only 90% of these values shall be considered to account for decreased atmospheric pressure during rain storm events. For example, at an elevation of 457 m (1,500 feet) atmospheric pressure used for calculations shall be 0.90 x 9.81 = 8.83 m (29.0 ft) w.c.

APPENDIX B: GENERAL QUALIFICATIONS AND REQUIREMENTS (INFORMATIVE)

The purpose of this non-mandatory appendix section is to describe the general requirements and qualifications of siphonic roof drain system Designers that may be useful to code officials and other parties requiring more information on how to apply this Standard.

This appendix section is not mandatory. It is not the policy of ASPE to dictate licensing, regulatory, or code requirements. This is the purview of state and local inspectional and licensing authorities. Inspectional authorities may choose to consider parts of this section when deciding on siphonic roof drainage equivalency.

As an “engineered system” or “special plumbing design,” siphonic roof drains and connected piping should be specified by qualified Designers of siphonic roof drainage piping systems. Siphonic roof drainage systems, as a matter of law, should be engineered by licensed Professional Engineers practicing in the discipline of mechanical or civil engineering. Construction drawings and specifications should be stamped and signed by the Professional Engineer responsible for the design.

Local code enforcement and administration officials who are not engineers cannot be expected to evaluate the technical merits of engineered siphonic roof drainage systems. Therefore, the engineer has the responsibility of demonstrating to the official having jurisdiction that the engineered system offers the same equivalency in quality, strength, performance, effectiveness, fire resistance, and safety.

Signed and stamped drawings and specifications should be filed with the inspectional authority having jurisdiction prior to construction. The submission of such drawings and specifications, stamped and signed by a Professional Engineer licensed in the jurisdiction, should be considered to be prima facea evidence that the design is consistent with accepted practices and principles and that the person stamping and signing such documents and/or the employer of this person takes sole responsibility for the safety and welfare of the public and the preservation of property offered by the application of the designed siphonic drainage system.

Only licensed plumbing contractors should install siphonic roof drains and connected drainage systems. With a properly engineered and documented design, there should be no reason for “specialty installers” who are otherwise not licensed plumbing contractors.

Under no circumstances should siphonic roof drains or siphonic roof drainage piping systems be installed without construction documents signed by a licensed Professional Engineer. The pipe dimensioning, drain positioning, and system configuration cannot be determined by the standards applied for atmospheric gravity systems and such installation cannot be accomplished by a licensed plumber alone.

APPENDIX C: REFERENCES AND RESOURCES (INFORMATIVE)

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