A SunCam online continuing education course

Water Flow in Pipes

The Hazen-Williams Formula

and the

SunCam Hydro-Calc Tool for Engineers

by

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SunCam, Inc.

Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.
No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		3.34201	Cubic Feet/Sec
	Quantity of flow	1500	1500.00000	US Gallons/Minute
	Quantity of flow		0.09464	Cubic Meters/Sec
	Quantity of flow		5678.11800	Liters/Minute
V	Velocity of flow		4.25518	Feet/Sec
	Velocity of flow		1.29698	Meters/Sec
C	Roughness coefficient	120	120.00000	No Units
R	Hydraulic Radius (a/p)		0.25000	Feet
	Hydraulic Radius (a/p)		0.07620	Meters
	Pipe Diameter	12	12.00000	Inches
	Pipe Diameter		30.48000	Centimeters
S	Hydraulic slope		0.00623	Feet/Foot or Meter/Meter
	Pressure Drop		0.00270	Pounds/Square Inch/Foot
	Pressure Drop		1.89968	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 1

Introduction

The Hazen & Williams Formula, developed in the early 1900s by Allan Hazen and Gardner Williams, is commonly used to compute the flow of water through pipes in water distributions systems, irrigation systems, fire sprinkler systems and sewer force mains. The formula in its various forms is listed below. The SunCam Hydro-Calc tool was developed using these equations and the following variables:

The Hazen & Williams Formula:

(1) $V = kcR^{0.63}\, S^{0.54}$ or

(2) $Q = aV = kacR^{0.63}\, S^{0.54}$

Where:

		In US customary units	In Metric units
V=	Mean velocity	Feet per second	Meters per second
Q=	Quantity of flow	Cubic Feet per second	Cubic Meters per second
K=	Conversion factor constant for the unit system	1.318	0.849
a=	Cross-sectional area of the pipe	Square Feet	Square meters
c=	Hazen & Williams coefficient of roughness	See Appendix "A."	
R=	Hydraulic radius (cross-sectional area of conduit divided by the wetted perimeter)	Feet	Meters
S=	Hydraulic slope	Any linear measure of head divided by the same linear measure of pipe length such as feet/foot or meters/meter. Note, some alternate measures of head: 1 foot of head = 0.43302 Pounds/square inch 1 meter of head = 1000 Kilograms/square meter	

(3a) $a = 4\pi R^2$ (3b) $R = \sqrt{\frac{a}{4\pi}}$

Formula (1) above, restated:

(4) $c = \frac{V}{kR^{0.63}\,S^{0.54}}$

(5) $R = \left(\frac{V}{kcS^{0.54}}\right)^{\frac{1}{0.63}}$

(6) $S = \left(\frac{V}{kcR^{0.63}}\right)^{\frac{1}{0.54}}$

Formula (2) above, restated:

$aR^{0.63} = \frac{Q}{kcS^{0.54}}$

Substituting the value of "a" in formula (3a), this equation becomes:

$4\pi R^2 R^{0.63} = \frac{Q}{kcS^{0.54}}$

Which reduces to:

(7) $R = \left(\frac{Q}{4k\pi cS^{0.54}}\right)^{\frac{1}{2.63}}$

The input tracking cell (A26) tells the user whether the input criteria have been met based on the following restrictions:

- Precisely three fields must have input to calculate outputs for all variables.
- The 3-inputs cannot be "Q," "V," and "R" or the problem will be over-determined.
- If you input any two of "Q," "V," or "R," the third of those variables will be calculated but "C" and "S" will not.

The input tracking cell displays one of the following messages to alert users about the status of inputs.

- ***"Please Input Data"***
- ***"Need More Input Data"***
- ***"Inputs OK"***
- ***"Too Much Input Data"***
- ***"Q, V, R Input Not Valid"***
- ***"Partial Results"***

Software Precautions

A professional engineer should have a healthy skepticism about all software outputs, even the software that you write yourself. Most state engineering boards have adopted rules to guide engineers similar to the Florida rule which states:

"61G15-30.008 Use of Computer Software and Hardware.
The engineer shall be responsible for the results generated by any computer software and hardware that he or she uses in providing engineering services."

We recommend the following best practices:

1. Test new software with known sets of data.
2. Always guess the outcome before you do the calculations (this is recommended for all calculations, not just software).
3. Ask yourself if the answer "looks right". (Also recommended for all calculations.)
4. When any of these cast doubt on the software output use hand calculations or alternative software to crosscheck and verify results.

The following are sample problems that illustrate the use of the Hazen & Williams Formula and the SunCam Hydro-Calc tool. You will probably find that some of the issues are not as complex as the problems that you encounter in real life. We hope that our simplified illustrations will still serve the purpose of aiding in the understanding of the principles and the process.

Sample Problem 1

The Tipsy-Gypsy Beverage Company is building a new bottling plant and wants to connect to the city water distribution system. Tipsy-Gypsy will be required to install a pipeline 1,000 feet in length to connect the plant to a large city water main. The plant needs 350 gallons of water per minute (gallons/minute) for its regular operations, but the Fire Department required an additional capacity of 1,500 gallons/minute for fire protection with a maximum of 20 pounds per square inch (psi) total pressure drop from the large main to the plant.

Pete Zacarian P.E., the engineer for the project selected asphalt-coated cast iron pipe with a roughness coefficient c=110 and applied a safety factor of 15% to the total flow. He used the SunCam Hydro-Calc tool to calculate the pipe size required for the job entering:

- =(350+1500)*1.15 in the input cell for Q in U.S. Gallons/Minute
- 110 in the input cell for C, roughness coefficient
- =20/1000 in the input cell for S, Pounds/Square Inch/Foot

The resulting calculated pipe size was 9.39 inches. (See Figure 2)

=(350+1500)*

=20/1000

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.

No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		4.74009	Cubic Feet/Sec
	Quantity of flow	2127.5	2127.50000	US Gallons/Minute
	Quantity of flow		0.13422	Cubic Meters/Sec
	Quantity of flow		8053.46404	Liters/Minute
V	Velocity of flow		9.85221	Feet/Sec
	Velocity of flow		3.00295	Meters/Sec
C	Roughness coefficient	110	110.00000	No Units
R	Hydraulic Radius (a/p)		0.19567	Feet
	Hydraulic Radius (a/p)		0.05964	Meters
	Pipe Diameter		9.39210	Inches
	Pipe Diameter		23.85593	Centimeters
S	Hydraulic slope		0.04613	Feet/Foot or Meter/Meter
	Pressure Drop	0.02	0.02000	Pounds/Square Inch/Foot
	Pressure Drop		14.06139	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 2

Zacarian reported to Tipsy-Gypsy that a 10-inch asphalt coated cast iron pipe would be adequate to meet current needs but recommended a 12-inch line to allow for future growth. Tipsy-Gypsy management accepted the recommendation and installed the 12-inch pipe.

A few years later, Tipsy-Gypsy decided to double the bottling capacity of the plant which would raise the regular operating demand to 700 gallons/minute. A city ordinance passed in the intervening years also increased the required fire flow rate from 1,500 gallons/minute to 3,000 gallons/minute with the same pressure drop limitation as before. Zacarian calculated the capacity of the 12-inch line using Hydro-Calc tool by entering:

- 110 in the input cell for C, roughness coefficient
- 12 for R, Pipe Diameter in Inches
- =20/1000 in the input cell for S, Pounds/Square Inch/Foot

The resulting calculated Q was 4,053 Gallons/Minute (See Figure 3)

=20/1000

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.
No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		9.02958	Cubic Feet/Sec
	Quantity of flow		4052.75509	US Gallons/Minute
	Quantity of flow		0.25569	Cubic Meters/Sec
	Quantity of flow		15341.34776	Liters/Minute
V	Velocity of flow		11.49681	Feet/Sec
	Velocity of flow		3.50423	Meters/Sec
C	Roughness coefficient	110	110.00000	No Units
R	Hydraulic Radius (a/p)		0.25000	Feet
	Hydraulic Radius (a/p)		0.07620	Meters
	Pipe Diameter	12	12.00000	Inches
	Pipe Diameter		30.48000	Centimeters
S	Hydraulic slope		0.04613	Feet/Foot or Meter/Meter
	Pressure Drop	0.02	0.02000	Pounds/Square Inch/Foot
	Pressure Drop		14.06139	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 3

Field fire flow tests showed 3,800 Gallons/Minute which demonstrated that the pipe was of adequate size for the proposed expansion.

Curious about the slight differences between the calculated and field measured capacity Zacarian used Hydro-Calc tool to make an additional computation. He entered:

- 3800 in the input cell for Q in U.S. Gallons/Minute

- 12 for R, Pipe Diameter in Inches
- =20/1000 in the input cell for S, Pounds/Square Inch/Foot

The resulting calculated C was 103 (See Figure 4) which suggested that perhaps the pipe was not as smooth as it had been when first installed or maybe it never was.

=20/1000

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.
No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		8.46644	Cubic Feet/Sec
	Quantity of flow	3800	3800.00000	US Gallons/Minute
	Quantity of flow		0.23974	Cubic Meters/Sec
	Quantity of flow		14384.56561	Liters/Minute
V	Velocity of flow		10.77980	Feet/Sec
	Velocity of flow		3.28568	Meters/Sec
C	Roughness coefficient		103.13971	No Units
R	Hydraulic Radius (a/p)		0.25000	Feet
	Hydraulic Radius (a/p)		0.07620	Meters
	Pipe Diameter	12	12.00000	Inches
	Pipe Diameter		30.48000	Centimeters
S	Hydraulic slope		0.04613	Feet/Foot or Meter/Meter
	Pressure Drop	0.02	0.02000	Pounds/Square Inch/Foot
	Pressure Drop		14.06139	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 4

He decided to make one further calculation. He entered:

- 3800 in the input cell for Q in U.S. Gallons/Minute
- 110 in the input cell for C, roughness coefficient
- =20/1000 in the input cell for S, Pounds/Square Inch/Foot

The resulting calculated Pipe Diameter was 11.71 Inches (see figure 5).

=20/1000

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.
No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		8.46644	Cubic Feet/Sec
	Quantity of flow	3800	3800.00000	US Gallons/Minute
	Quantity of flow		0.23974	Cubic Meters/Sec
	Quantity of flow		14384.56561	Liters/Minute
V	Velocity of flow		11.32083	Feet/Sec
	Velocity of flow		3.45059	Meters/Sec
C	Roughness coefficient	110	110.00000	No Units
R	Hydraulic Radius (a/p)		0.24395	Feet
	Hydraulic Radius (a/p)		0.07436	Meters
	Pipe Diameter		11.70975	Inches
	Pipe Diameter		29.74276	Centimeters
S	Hydraulic slope		0.04613	Feet/Foot or Meter/Meter
	Pressure Drop	0.02	0.02000	Pounds/Square Inch/Foot
	Pressure Drop		14.06139	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 5

In his final report, he concluded that even a small amount of encrustation on the inner lining of the pipe would result in both a reduction in smoothness and diameter of the pipe, which would explain the slight difference between the predicted system capacity and the field measured capacity.

Sample Problem 2

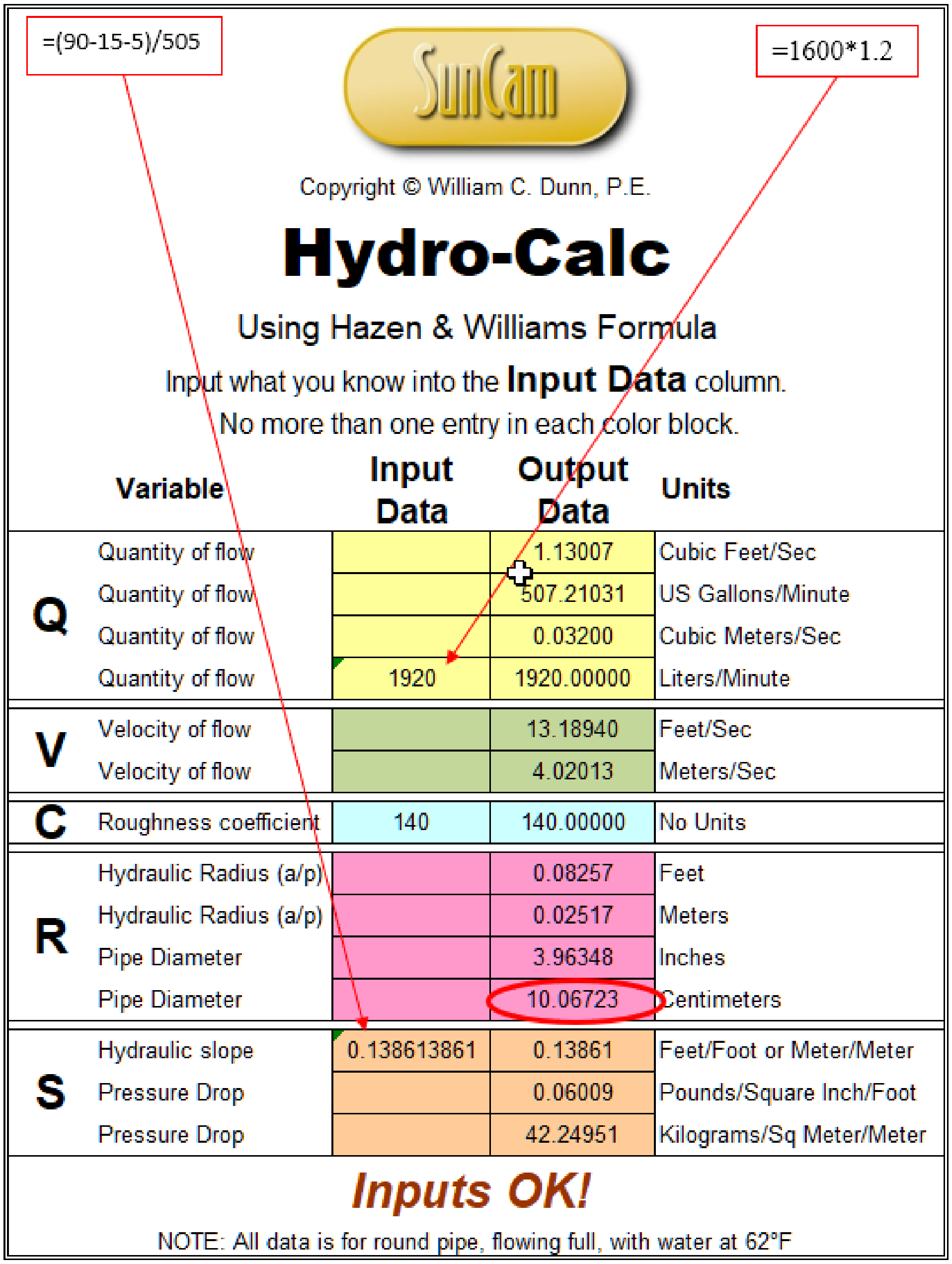
A small Italian town commissions an artist, Alfredo Alto, to create a fountain for the main square. Alto will design and build the fountain, but it will be the responsibility of his client to construct a pipeline from a lake in the mountains above the town to the fountain. The artist and the engineer for the town, consultant Benito Giovanni, meet to agree on the water pressure and volume of flow requirements. They agree on a flow rate of 1600 Liters/Minute and a head (pressure) of 15 meters of water.

Giovanni conducts a field route survey for the pipeline and determines that 505 meters of pipe will be required and the elevation of the water in the mountain lake is 90 meters above the level of water in the fountain. Therefore, he concludes that the available head is 75 meters (90-15). He applies a 20% safety factor to increase the design quantity of flow and a 5-meter safety factor to reduce the available head. He used the SunCam Hydro-Calc tool to calculate the pipe size required for the job by entering:

- =1600*1.2 in the input cell for Q in Liters/Minute
- 140 in the input cell for C, roughness coefficient (for PVC pipe)
- =(90-15-5)/505 in the input cell for S, Feet/Foot or Meter/Meter

The resulting calculated pipe size is 10.07 Centimeters (100.7 mm). (See Figure 6)

To avoid water hammer problems for this long pipeline, Giovanni uses a butterfly valve with a gear operator and damper to keep pressure surges well within the bursting strength of the pipe.



=(90-15-5)/505

=1600*1.2

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.
No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		1.13007	Cubic Feet/Sec
	Quantity of flow		507.21031	US Gallons/Minute
	Quantity of flow		0.03200	Cubic Meters/Sec
	Quantity of flow	1920	1920.00000	Liters/Minute
V	Velocity of flow		13.18940	Feet/Sec
	Velocity of flow		4.02013	Meters/Sec
C	Roughness coefficient	140	140.00000	No Units
R	Hydraulic Radius (a/p)		0.08257	Feet
	Hydraulic Radius (a/p)		0.02517	Meters
	Pipe Diameter		3.96348	Inches
	Pipe Diameter		10.06723	Centimeters
S	Hydraulic slope	0.138613861	0.13861	Feet/Foot or Meter/Meter
	Pressure Drop		0.06009	Pounds/Square Inch/Foot
	Pressure Drop		42.24951	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

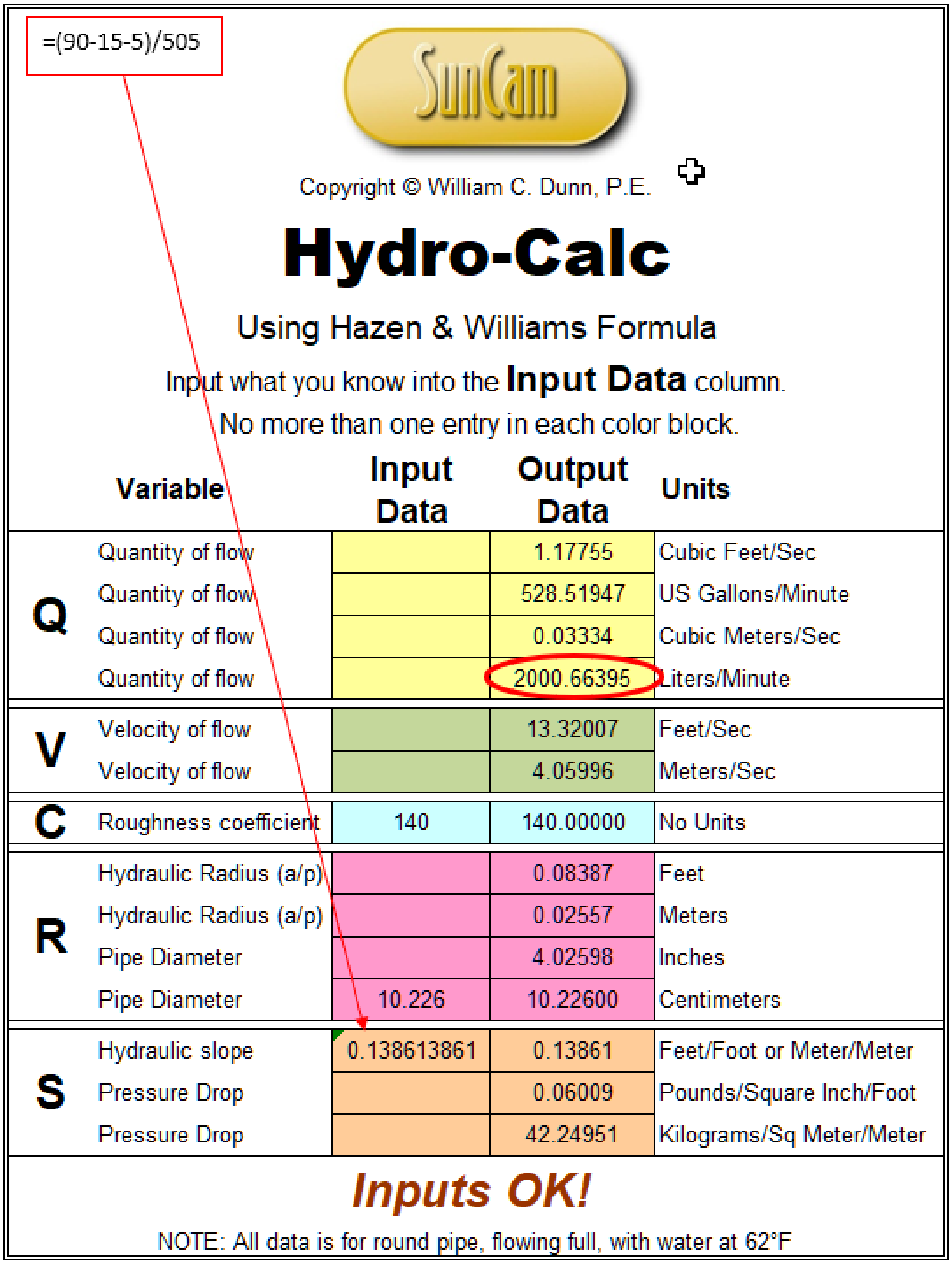
Figure 6

Giovanni makes a preliminary selection of 100 mm Schedule 40 PVC which has an actual internal diameter of 102.26 mm. He uses Hydro-Calc tool to check the pipe size by entering:

- 140 in the input cell for C, roughness coefficient (for PVC pipe)
- 10.226 in the input cell for R, Pipe Diameter in Centimeters

- =(90-15-5)/505 in the input cell for S, Feet/Foot or Meter/Meter

The resulting quantity of flow is 2001 Liters/Minute. (see figure 7)


=(90-15-5)/505

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.

No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		1.17755	Cubic Feet/Sec
	Quantity of flow		528.51947	US Gallons/Minute
	Quantity of flow		0.03334	Cubic Meters/Sec
	Quantity of flow		2000.66395	Liters/Minute
V	Velocity of flow		13.32007	Feet/Sec
	Velocity of flow		4.05996	Meters/Sec
C	Roughness coefficient	140	140.00000	No Units
R	Hydraulic Radius (a/p)		0.08387	Feet
	Hydraulic Radius (a/p)		0.02557	Meters
	Pipe Diameter		4.02598	Inches
	Pipe Diameter	10.226	10.22600	Centimeters
S	Hydraulic slope	0.138613861	0.13861	Feet/Foot or Meter/Meter
	Pressure Drop		0.06009	Pounds/Square Inch/Foot
	Pressure Drop		42.24951	Kilograms/Sq Meter/Meter

Inputs OK!

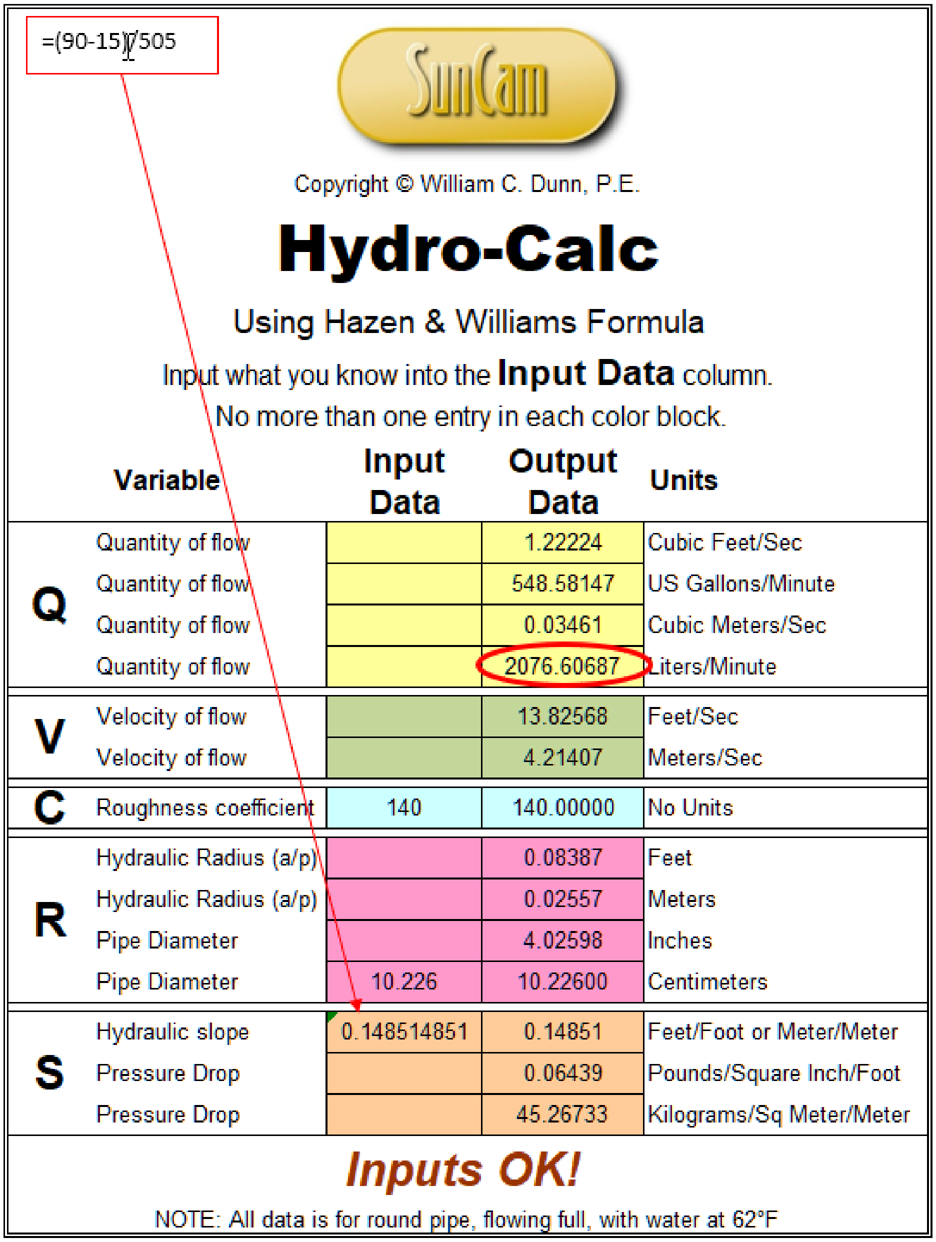
NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 7

As a last step, Giovanni uses Hydro-Calc tool to make a final calculation of the most likely volume of flow and pressure at the connection to the fountain. He enters:

- 140 in the input cell for C, roughness coefficient (for PVC pipe)
- 10.226 in the input cell for R, Pipe Diameter in Centimeters
- =(90-15)/505 in the input cell for S, Feet/Foot or Meter/Meter

The resulting quantity of flow is 2077 Liters/Minute which yields a safety factor of 30%. (see figure 8)


=(90-15)/505

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.
No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		1.22224	Cubic Feet/Sec
	Quantity of flow		548.58147	US Gallons/Minute
	Quantity of flow		0.03461	Cubic Meters/Sec
	Quantity of flow		2076.60687	Liters/Minute
V	Velocity of flow		13.82568	Feet/Sec
	Velocity of flow		4.21407	Meters/Sec
C	Roughness coefficient	140	140.00000	No Units
R	Hydraulic Radius (a/p)		0.08387	Feet
	Hydraulic Radius (a/p)		0.02557	Meters
	Pipe Diameter		4.02598	Inches
	Pipe Diameter	10.226	10.22600	Centimeters
S	Hydraulic slope	0.148514851	0.14851	Feet/Foot or Meter/Meter
	Pressure Drop		0.06439	Pounds/Square Inch/Foot
	Pressure Drop		45.26733	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 8

The Inevitable Change Order

A generous benefactor came forward with a donation to the fountain project that doubled the available budget, so the town asked Alto and Giovanni to revise their plans. Giovanni had already completed construction of 150 meters of the pipeline from the lake down the slope toward the fountain. In a meeting between artist and engineer, they agreed on a new flow rate of 2500 Liters/Minute and a head at the fountain of 25 meters of water.

Giovanni used Hydro-Calc tool to update the hydraulic calculations for the project by entering:

- 140 in the input cell for C, roughness coefficient (for PVC pipe)
- 10.226 in the input cell for R, Pipe Diameter in Centimeters
- =(90-25)/505 in the input cell for S, Feet/Foot or Meter/Meter

=(90-25)/505

Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.
No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		1.13135	Cubic Feet/Sec
	Quantity of flow		507.78663	US Gallons/Minute
	Quantity of flow		0.03204	Cubic Meters/Sec
	Quantity of flow		1922.18161	Liters/Minute
V	Velocity of flow		12.79755	Feet/Sec
	Velocity of flow		3.90069	Meters/Sec
C	Roughness coefficient	140	140.00000	No Units
R	Hydraulic Radius (a/p)		0.08387	Feet
	Hydraulic Radius (a/p)		0.02557	Meters
	Pipe Diameter		4.02598	Inches
	Pipe Diameter	10.226	10.22600	Centimeters
S	Hydraulic slope	0.128712871	0.12871	Feet/Foot or Meter/Meter
	Pressure Drop		0.05580	Pounds/Square Inch/Foot
	Pressure Drop		39.23168	Kilograms/Sq Meter/Meter

Inputs OK!

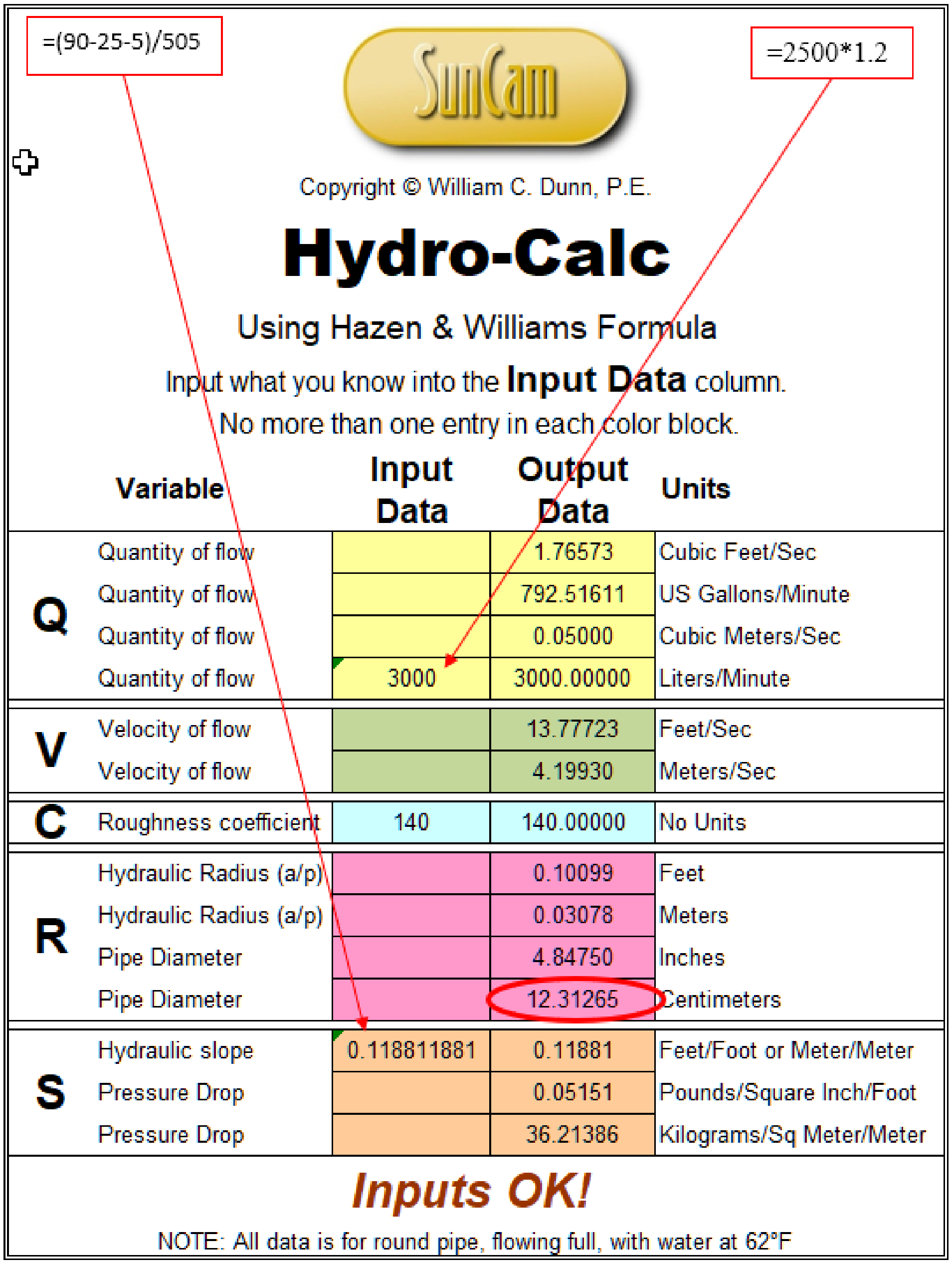
NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 9

This resulted in a quantity of flow of 1922 liters per minute, far short of the required volume even without applying safety factors. He then checks to see what pipe size would be needed if he removed all of the newly laid pipe. He changes the entries to:

- =2500*1.2 in the input cell for Q in Liters/Minute

- 140 in the input cell for C, roughness coefficient (for PVC pipe)
- =(90-25-5)/505 in the input cell for S, Feet/Foot or Meter/Meter


=(90-25-5)/505

=2500*1.2

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.

No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		1.76573	Cubic Feet/Sec
	Quantity of flow		792.51611	US Gallons/Minute
	Quantity of flow		0.05000	Cubic Meters/Sec
	Quantity of flow	3000	3000.00000	Liters/Minute
V	Velocity of flow		13.77723	Feet/Sec
	Velocity of flow		4.19930	Meters/Sec
C	Roughness coefficient	140	140.00000	No Units
R	Hydraulic Radius (a/p)		0.10099	Feet
	Hydraulic Radius (a/p)		0.03078	Meters
	Pipe Diameter		4.84750	Inches
	Pipe Diameter		12.31265	Centimeters
S	Hydraulic slope	0.118811881	0.11881	Feet/Foot or Meter/Meter
	Pressure Drop		0.05151	Pounds/Square Inch/Foot
	Pressure Drop		36.21386	Kilograms/Sq Meter/Meter

Inputs OK!

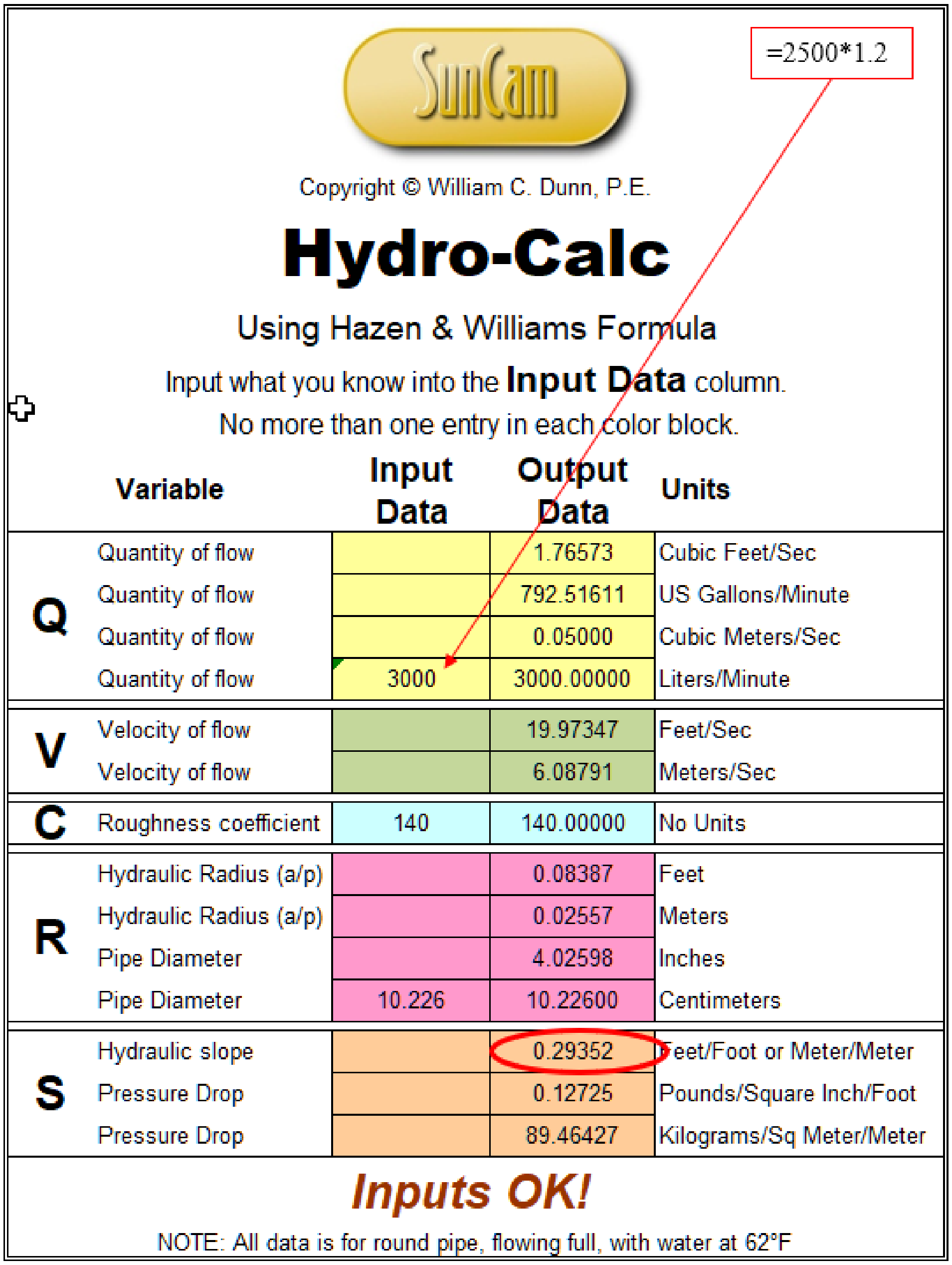
NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 10

The resulting calculated pipe size is 12.31 Centimeters (123.1 mm) (see figure 10). Giovanni makes a preliminary selection of 125 mm Schedule 40 PVC which has an actual internal diameter of 128.2 mm.

Giovanni would like to avoid removing the newly installed pipe because it lay along the steepest, roughest and most expensive portion of the route. He believes that it may be more economical to just increase the size of the remaining pipe rather than removing the newly laid pipe. He uses Hydro-Calc tool to determine a pipe size to finish the job with a pipe size that would deliver the required quantity of flow and pressure. He enters:

- =2500*1.2 in the input cell for Q in Liters/Minute
- 140 in the input cell for C, roughness coefficient (for PVC pipe)
- 10.226 in the input cell for R, Pipe Diameter in Centimeters



=2500*1.2

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.
No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		1.76573	Cubic Feet/Sec
	Quantity of flow		792.51611	US Gallons/Minute
	Quantity of flow		0.05000	Cubic Meters/Sec
	Quantity of flow	3000	3000.00000	Liters/Minute
V	Velocity of flow		19.97347	Feet/Sec
	Velocity of flow		6.08791	Meters/Sec
C	Roughness coefficient	140	140.00000	No Units
R	Hydraulic Radius (a/p)		0.08387	Feet
	Hydraulic Radius (a/p)		0.02557	Meters
	Pipe Diameter		4.02598	Inches
	Pipe Diameter	10.226	10.22600	Centimeters
S	Hydraulic slope		0.29352	Feet/Foot or Meter/Meter
	Pressure Drop		0.12725	Pounds/Square Inch/Foot
	Pressure Drop		89.46427	Kilograms/Sq Meter/Meter

Inputs OK!

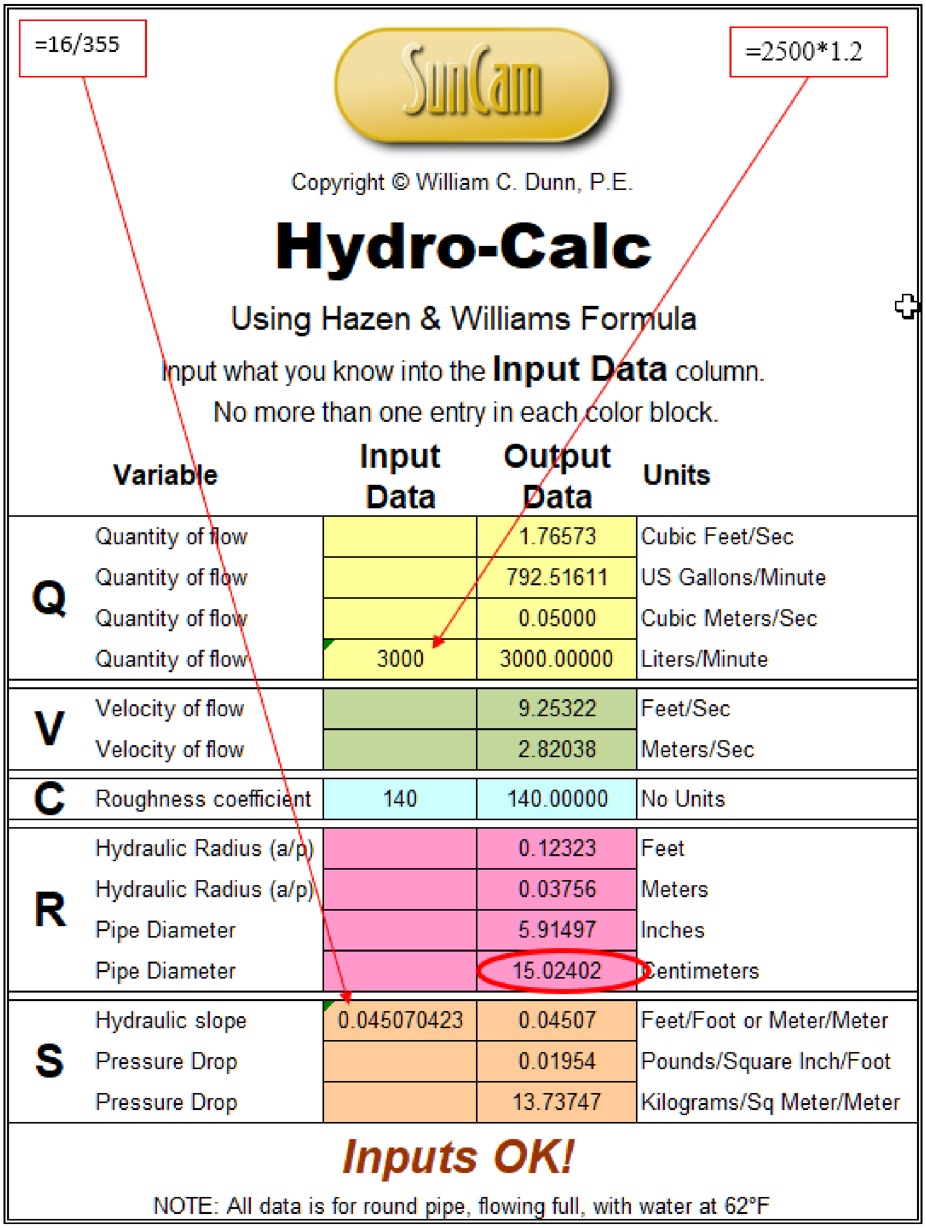
NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 11

The resulting hydraulic slope is 0.294 meters per meter which means the 150 meters of newly laid pipe will consume 44 meters (0.294*150) of the available head leaving 16 meters of head (90-25-44-5) for the remaining 355 meters of the pipeline. (This includes 5 meters of safety margin.)

Giovanni uses Hydro-Calc tool to see what pipe size would work for the remaining 355 meters. He enters:

- =2500*1.2 in the input cell for Q in Liters/Minute
- 140 in the input cell for C, roughness coefficient (for PVC pipe)
- =16/355 in the input cell for S, Feet/Foot or Meter/Meter


=16/355
=2500*1.2
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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.
No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		1.76573	Cubic Feet/Sec
	Quantity of flow		792.51611	US Gallons/Minute
	Quantity of flow		0.05000	Cubic Meters/Sec
	Quantity of flow	3000	3000.00000	Liters/Minute
V	Velocity of flow		9.25322	Feet/Sec
	Velocity of flow		2.82038	Meters/Sec
C	Roughness coefficient	140	140.00000	No Units
R	Hydraulic Radius (a/p)		0.12323	Feet
	Hydraulic Radius (a/p)		0.03756	Meters
	Pipe Diameter		5.91497	Inches
	Pipe Diameter		15.02402	Centimeters
S	Hydraulic slope	0.045070423	0.04507	Feet/Foot or Meter/Meter
	Pressure Drop		0.01954	Pounds/Square Inch/Foot
	Pressure Drop		13.73747	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 12

The resulting calculated pipe size is 15.02 Centimeters (150.2 mm). Giovanni makes a preliminary choice of 150 mm Schedule 40 PVC which has an actual internal diameter of 154.0 mm.

Giovanni decided that the fastest and most economical alternative was to complete the job using 150 mm PVC pipe. He assured the town mayor, the contractor, and the artist that the 100-mm pipe feeding into a 150-mm pipe will not create a "bottleneck" and that the hydraulic calculations were sound. The finished fountain and pipeline functioned just as intended.

Sample Problem 3

A small historic town exists within a perimeter levy on land that lies slightly below sea level. It uses a central canal system to collect stormwater and convey it to the intake side of a pump station on the perimeter levy. The pump station utilizes three pumps to maintain a constant elevation of water in the collector canal of 3.0 feet below mean high water. The discharge of the pump station empties into a 500-foot long pipe that in turn drains into a wide canal that carries the water to the Gulf of Mexico for release.

Pump #1	Operates continuously even in drought conditions to maintain the low water elevation.	90 Cubic Feet/Second (CFS)
Pump #2	Operates along with Pump #1 during routine rainfall events	90 CFS
Pump #3	Operates along with Pumps # 1 & 2 during extreme rainfall events	200 CFS

A federal judge has issued a ruling that the town discontinues the direct discharge into the Gulf of Mexico except in extreme rainfall events. Under the court order, pumps # 1 & 2 will pump discharge water through a 6,000-foot long pipe to a polishing pond with water surface elevation of +5.0 above mean high water and marsh filter system. Pump #3 will continue to operate without change.

Arnold de Gerabon, the design engineer for the project, evaluates the existing Pumps # 1 & 2 and determines that they are capable of producing the design volume of flow at 10 feet of head. The 3 feet of suction lift plus 5 feet for the receiving waters means the available head-loss for the new pipe would be 2 feet. He uses the Hydro-Calc tool to size the pipe by entering:

- =90+90 in the input cell for Q in Cubic Feet/Sec
- 120 in the input cell for C, roughness coefficient (for concrete pipe)
- =2/6000 in the input cell for S, Feet/Foot or Meter/Meter

=2/6000

=90+90

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.
No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow	180	180.00000	Cubic Feet/Sec
	Quantity of flow		80789.60692	US Gallons/Minute
	Quantity of flow		5.09703	Cubic Meters/Sec
	Quantity of flow		305821.94771	Liters/Minute
V	Velocity of flow		3.32183	Feet/Sec
	Velocity of flow		1.01249	Meters/Sec
C	Roughness coefficient	120	120.00000	No Units
R	Hydraulic Radius (a/p)		2.07655	Feet
	Hydraulic Radius (a/p)		0.63293	Meters
	Pipe Diameter		99.67448	Inches
	Pipe Diameter		253.17319	Centimeters
S	Hydraulic slope	0.000333333	0.00033	Feet/Foot or Meter/Meter
	Pressure Drop		0.00014	Pounds/Square Inch/Foot
	Pressure Drop		0.10160	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

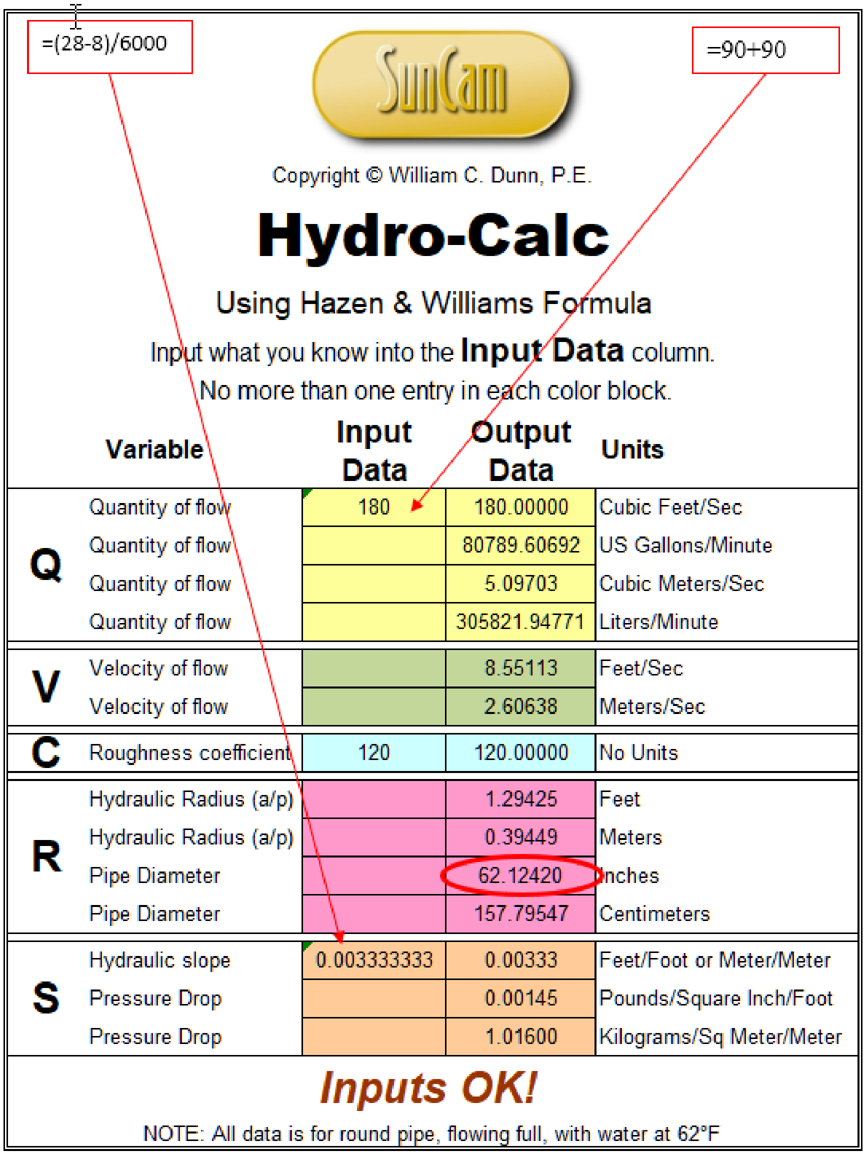
Figure 13

The resulting calculated pipe size is 99.67 inches. The nearest standard pipe size would be 108 inches (9 feet) diameter.

He then checks to see how much he could reduce the pipe size if he selects new, high-pressure pumps to replace Pumps # 1 & 2. The rating for each of the new pumps is 90 CFS at 28 feet of head.

He uses the Hydro-Calc tool to size the pipe by entering:

- =90+90 in the input cell for Q in Cubic Feet/Sec
- 120 in the input cell for C, roughness coefficient (for concrete pipe)
- =(28-8)/6000 in the input cell for S, Feet/Foot or Meter/Meter



	Variable	Input Data	Output Data	Units
Q	Quantity of flow	180	180.00000	Cubic Feet/Sec
	Quantity of flow		80789.60692	US Gallons/Minute
	Quantity of flow		5.09703	Cubic Meters/Sec
	Quantity of flow		305821.94771	Liters/Minute
V	Velocity of flow		8.55113	Feet/Sec
	Velocity of flow		2.60638	Meters/Sec
C	Roughness coefficient	120	120.00000	No Units
R	Hydraulic Radius (a/p)		1.29425	Feet
	Hydraulic Radius (a/p)		0.39449	Meters
	Pipe Diameter		62.12420	Inches
	Pipe Diameter		157.79547	Centimeters
S	Hydraulic slope	0.003333333	0.00333	Feet/Foot or Meter/Meter
	Pressure Drop		0.00145	Pounds/Square Inch/Foot
	Pressure Drop		1.01600	Kilograms/Sq Meter/Meter

Figure 14

The resulting calculated pipe size is 62.12 inches. The nearest standard pipe size would be 66 inches (5.5 feet) diameter.

He then checks the capacity of this design by entering:

- 120 in the input cell for C, roughness coefficient (for concrete pipe)
- 66 in the input cell for Diameter in Inches
- =(28-8)/6000 in the input cell for S, Feet/Foot or Meter/Meter

Hazen & Williams Formula

Input what you know into the **Input Data** column.
No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		211.05573	Cubic Feet/Sec
	Quantity of flow		94,728.38407	US Gallons/Minute
	Quantity of flow		5.97643	Cubic Meters/Sec
	Quantity of flow		358,585.96	Liters/Minute
V	Velocity of flow		8.88345	Feet/Sec
	Velocity of flow		2.70768	Meters/Sec
C	Roughness coefficient	120	120.00000	No Units
R	Hydraulic Radius (a/p)		1.37500	Feet
	Hydraulic Radius (a/p)		0.41910	Meters
	Pipe Diameter	66	66.00000	Inches
	Pipe Diameter		167.64000	Centimeters
S	Hydraulic slope	0.003333333	0.00333	Feet/Foot or Meter/Meter
	Pressure Drop		0.00145	Pounds/Square Inch/Foot
	Pressure Drop		1.01600	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 15

The resulting calculated Quantity of flow is 211 CFS which yields a 17% factor of safety. Arnold selects his alternative for lower initial cost and lower life-cycle cost.

Sample Problem 4

Rancher Dan Mullins purchased an 80-acre pasture adjacent to his existing 320-acre ranch. He wants to pasture 160 head of cattle on this land, but he will need a source of about 10 gallons/minute of water (about 45 gallons per cow for the 12 hours of daylight). Dan has an existing well and pump at his barn which he tests by filling a 55-gallon drum in about a minute using a 1-inch poly pipe. Based on this test he decides to put a stock tank out in the new pasture and to run a 1-inch polyethylene pipe the 2600 feet back to his well at the barn.

When he completes the new watering system, the pipe produces only a trickle at the upper pasture. Dan measures the flow by timing the filling of a 5-gallon can. It takes 4-minutes. At this rate of flow, he could only water only about 10% of the herd.

Dan decided to call his wife's sister, Sonia Stephens, a professional engineer. Sonia stopped by after work and brought a pocket altimeter and her laptop computer with Hydro-Calc tool installed. She and Dan first visited the well and pump. The discharge pressure gage read 55psi which was very close to the maximum pressure rating for the pump. She took an altimeter reading at the level of the pump which read 260.5 feet. They then drove the half mile to the upper pasture where Sonia took another altimeter reading at the pipe discharge and got an altitude of 383.0 feet. This placed the pipe discharge 122.5 feet (383.0-260.5) above the pump. The elevation alone consumed 53 psi (122.5'*.433psi/ft) of the available 55 psi, and when she raised the end of the flowing pipe above her head, the flow stopped completely. The location of the stock tank appeared to Sonia to be the highest point on the 80-acre parcel. Sonia was aware that the Hazen-Williams formula is not accurate for pipe diameters smaller than 3-inches, but she used Hydro-Calc tool to get an approximate evaluation of the conditions. She entered:

- 140 in the input cell for C, roughness coefficient (for Poly-pipe)
- 1 in the input cell for R, Pipe Diameter in inches
- =2/2600 in the input cell for S, Pounds/Square Inch/Foot

=2/2600

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.
No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		0.00287	Cubic Feet/Sec
	Quantity of flow		1.28870	US Gallons/Minute
	Quantity of flow		0.00008	Cubic Meters/Sec
	Quantity of flow		4.87828	Liters/Minute
V	Velocity of flow		0.52643	Feet/Sec
	Velocity of flow		0.16046	Meters/Sec
C	Roughness coefficient	140	140.00000	No Units
R	Hydraulic Radius (a/p)		0.02083	Feet
	Hydraulic Radius (a/p)		0.00635	Meters
	Pipe Diameter	1	1.00000	Inches
	Pipe Diameter		2.54000	Centimeters
S	Hydraulic slope		0.00177	Feet/Foot or Meter/Meter
	Pressure Drop	0.000769231	0.00077	Pounds/Square Inch/Foot
	Pressure Drop		0.54082	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 16

The resulting quantity of flow (Q) was 1.29 gallons/minute which seemed to match the observed rate.

Sonia could see where Dan had buried the pipe, so she walked along the route some 1450 feet until she came to a relatively low point in the new pasture. She measured the altitude at that point to be 279.0 feet. She calculated that the difference in elevation from the pump to this area was 18.5 feet which is equivalent to 8 psi (18.5'*.433psi/ft) so, the free head would now be 47 psi (55-8). The length of pipe to this point would be 1150 feet (2600-1450). She used Hydro-Calc tool again to approximate the conditions by entering:

- 140 in the input cell for C, roughness coefficient (for Poly-pipe)
- 1 in the input cell for R, Pipe Diameter in inches
- =47/1150 in the input cell for S, Pounds/Square Inch/Foot

=47/1150

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.
No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		0.02453	Cubic Feet/Sec
	Quantity of flow		11.01131	US Gallons/Minute
	Quantity of flow		0.00069	Cubic Meters/Sec
	Quantity of flow		41.68233	Liters/Minute
V	Velocity of flow		4.49809	Feet/Sec
	Velocity of flow		1.37102	Meters/Sec
C	Roughness coefficient	140	140.00000	No Units
R	Hydraulic Radius (a/p)		0.02083	Feet
	Hydraulic Radius (a/p)		0.00635	Meters
	Pipe Diameter	1	1.00000	Inches
	Pipe Diameter		2.54000	Centimeters
S	Hydraulic slope		0.09427	Feet/Foot or Meter/Meter
	Pressure Drop	0.040869565	0.04087	Pounds/Square Inch/Foot
	Pressure Drop		28.73415	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 17

The computed quantity of flow for this new location was 11 gallons/minute, slightly more than Dan's herd needed. Dan immediately uncovered the pipe and cut through it with the blade of his shovel which covered him with water and mud from the geyser. The next day he relocated the stock tank and began moving cattle into the new pasture.

Sample Problem 5

Eleanor Watson is chief engineer for the water distribution system for a major city. One element of her job is to conduct fire flow tests on the system and coordinate the testing with the fire department. When developers propose a warehouse building for an industrial park in an older part of the city she issues a flow test order which reads:

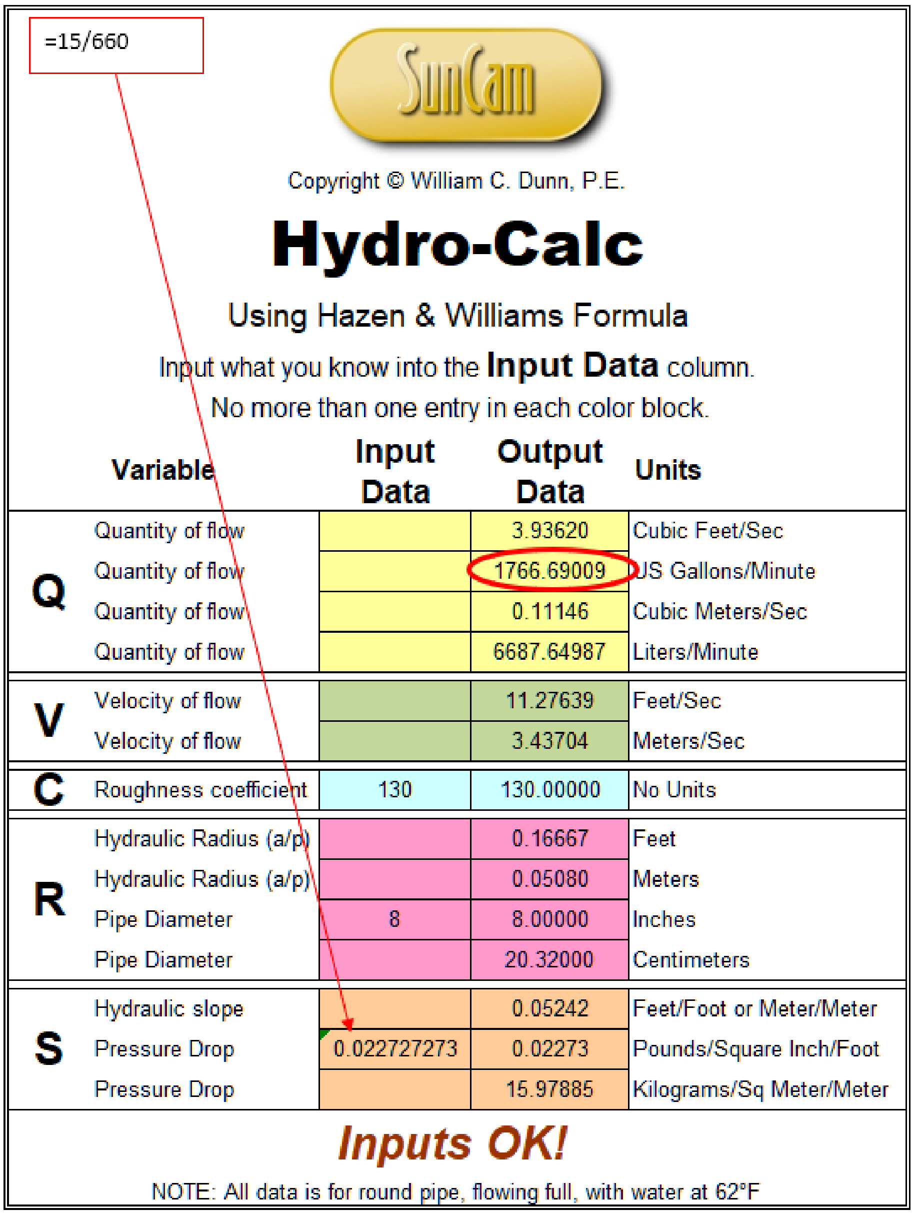
Conduct a fire flow test on an existing hydrant located at W. 23 St. and Woodrow Ave. Three pipelines feed the hydrant; all three pipes connect to the same 24" DIP Transmission main.

Seg.	*Size/Type*	*Length*	*C*	*Q**
A	*8" PVC*	*660'*	*130*	*1,767 gallons/minute*
B	*12" DIP*	*330'*	*120*	*6,888 gallons/minute*
C	*6" ACP*	*990'*	*140*	*717 gallons/minute*
Expected test results				*9,372 gallons/minute*
Required minimum flow				*4,000 gallons/minute*
** Based on a maximum of 15 pounds per square inch (psi) total pressure drop from the feeder main per fire flow ordinance.*				

Eleanor calculated the quantity of flow (Q) for each pipeline using Hydro-Calc tool by making the following entries:

Segment A:

- 130 in the input cell for C, roughness coefficient
- 8 in the input cell for R, Pipe Diameter in inches
- =15/660 in the input cell for S, Pounds/Square Inch/Foot


=15/660

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.

No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		3.93620	Cubic Feet/Sec
	Quantity of flow		1766.69009	US Gallons/Minute
	Quantity of flow		0.11146	Cubic Meters/Sec
	Quantity of flow		6687.64987	Liters/Minute
V	Velocity of flow		11.27639	Feet/Sec
	Velocity of flow		3.43704	Meters/Sec
C	Roughness coefficient	130	130.00000	No Units
R	Hydraulic Radius (a/p)		0.16667	Feet
	Hydraulic Radius (a/p)		0.05080	Meters
	Pipe Diameter	8	8.00000	Inches
	Pipe Diameter		20.32000	Centimeters
S	Hydraulic slope		0.05242	Feet/Foot or Meter/Meter
	Pressure Drop	0.022727273	0.02273	Pounds/Square Inch/Foot
	Pressure Drop		15.97885	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 18 - Segment A

Segment B:

- 120 in the input cell for C, roughness coefficient
- 12 in the input cell for R, Pipe Diameter in inches
- =15/330 in the input cell for S, Pounds/Square Inch/Foot

=15/330

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.
No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		15.34587	Cubic Feet/Sec
	Quantity of flow		6887.70401	US Gallons/Minute
	Quantity of flow		0.43455	Cubic Meters/Sec
	Quantity of flow		26072.79741	Liters/Minute
V	Velocity of flow		19.53897	Feet/Sec
	Velocity of flow		5.95548	Meters/Sec
C	Roughness coefficient	120	120.00000	No Units
R	Hydraulic Radius (a/p)		0.25000	Feet
	Hydraulic Radius (a/p)		0.07620	Meters
	Pipe Diameter	12	12.00000	Inches
	Pipe Diameter		30.48000	Centimeters
S	Hydraulic slope		0.10485	Feet/Foot or Meter/Meter
	Pressure Drop	0.045454545	0.04545	Pounds/Square Inch/Foot
	Pressure Drop		31.95771	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 19 - Segment B

Segment C:

- 140 in the input cell for C, roughness coefficient
- 6 in the input cell for R, Pipe Diameter in inches
- =15/990 in the input cell for S, Pounds/Square Inch/Foot

=15/990

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.

No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		1.59803	Cubic Feet/Sec
	Quantity of flow		717.24396	US Gallons/Minute
	Quantity of flow		0.04525	Cubic Meters/Sec
	Quantity of flow		2715.06389	Liters/Minute
V	Velocity of flow		8.13868	Feet/Sec
	Velocity of flow		2.48067	Meters/Sec
C	Roughness coefficient	140	140.00000	No Units
R	Hydraulic Radius (a/p)		0.12500	Feet
	Hydraulic Radius (a/p)		0.03810	Meters
	Pipe Diameter	6	6.00000	Inches
	Pipe Diameter		15.24000	Centimeters
S	Hydraulic slope		0.03495	Feet/Foot or Meter/Meter
	Pressure Drop	0.015151515	0.01515	Pounds/Square Inch/Foot
	Pressure Drop		10.65257	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 20 Segment C

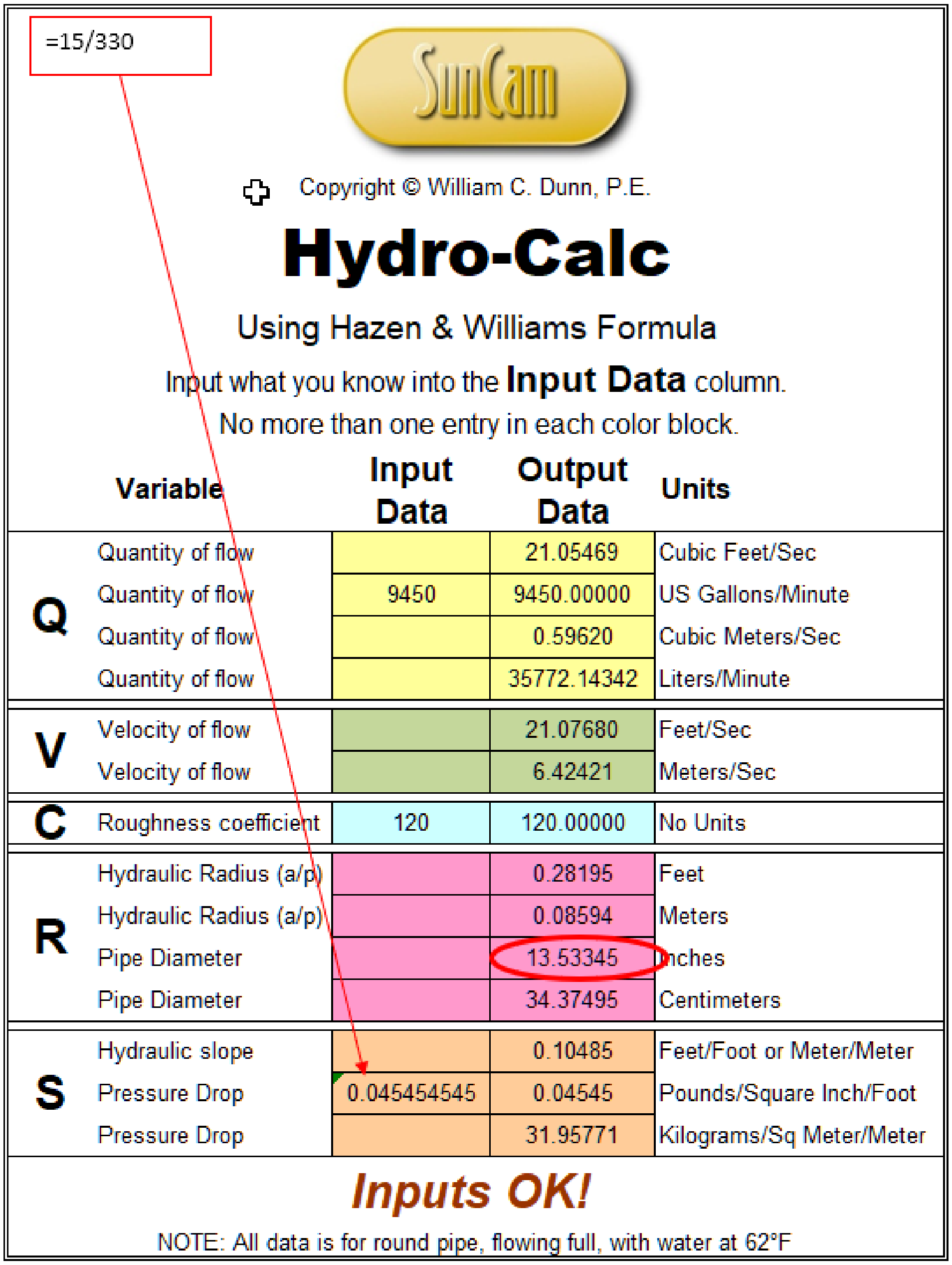
When the field crew conducted the test, the results were lower than expected at 2500 gallons/minute but the data in the order immediately suggested that there may be a problem with segment B, the 12” pipe. The crew was able to find a closed valve on that line. When they retested the fire flow, the results were 9450 gallons/minute, in line with expectations. By predicting the flows before conducting the test, Eleanor gave her crew the tools to not only discover the problem but to quickly solve it.

A few months after the flow test Eleanor received a phone call from the Risk Manager for the company who would occupy the warehouse. The insurance carrier for the new building was evaluating the fire risks and wanted to know both the fire flow test results *and* “the size of the water line serving the building or the equivalent pipe size if served by more than one pipe.”

Without hanging up the phone, Eleanor used Hydro-Calc tool and entered:

- 9450 in the input cell for Quantity of flow in gallons/minute
- 120 in the input cell for C, roughness coefficient (for ductile Iron Pipe)
- =15/330 in the input cell for S, Pounds/Square Inch/Foot*

** Based on a maximum of 15 pounds per square inch (psi) total pressure drop from the feeder main per fire flow ordinance and the shortest pipe length to the feeder main.*


=15/330

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.
No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		21.05469	Cubic Feet/Sec
	Quantity of flow	9450	9450.00000	US Gallons/Minute
	Quantity of flow		0.59620	Cubic Meters/Sec
	Quantity of flow		35772.14342	Liters/Minute
V	Velocity of flow		21.07680	Feet/Sec
	Velocity of flow		6.42421	Meters/Sec
C	Roughness coefficient	120	120.00000	No Units
R	Hydraulic Radius (a/p)		0.28195	Feet
	Hydraulic Radius (a/p)		0.08594	Meters
	Pipe Diameter		13.53345	Inches
	Pipe Diameter		34.37495	Centimeters
S	Hydraulic slope		0.10485	Feet/Foot or Meter/Meter
	Pressure Drop	0.045454545	0.04545	Pounds/Square Inch/Foot
	Pressure Drop		31.95771	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 21 Equivalent Pipe Diameter

The resulting equivalent pipe diameter was a 13.53-inch ductile iron pipe 330 feet in length. Her quick response to the question astonished the risk manager, and he entered these new facts in his report.

Sample Problem 6

John Hardcastle is a part-time farmer who grows corn and tomatoes on a long rectangular field 1900 feet long and 200 feet wide. He wants to install an irrigation system by locating a pump and well in the center of the field and a row of sprinkler heads down the middle of the 200-foot width in both directions. At an auction John purchased:

1. A diesel engine driven pump guaranteed to produce 1600 gallons/minute @115 psi
2. 1900 feet of 6" schedule 80 PVC pipe
3. 20 impact sprinklers rated at 115' radius @ 95 psi and 100 gallons/minute each.

He planned to bury 950' of the 6" PVC in each direction from the pump and install a sprinkler head every 100' along the pipe for head-to-head irrigation coverage. He would operate only ten sprinkler heads at a time so the maximum rate of flow would be 1000 gallons/minute, well below the 1600 gallons/minute rating of his pump.

John was uncertain about the hydraulic calculations so at the last minute he called in Jimmy Handley, an irrigation contractor. Jimmy listened patiently, and when he had heard the whole plan, he told John that his plan was a disaster in the making and that he should leave such serious matters to the experts. He explained that you could not use the same size pipe for the entire system because the sprinklers at the end of the run would have no pressure. The pipes have to step down in size to get pressure to the last sprinkler.

John had indeed seen many irrigation system installations, and he knew that the stepping down in pipe size that Jimmy described was commonplace. John was not an engineer, but he had given this issue a lot of thought and could not see how reducing pipe size could increase pressure. He decided to contact Jake Akins, the engineer at the Agricultural Extension Service.

John gave Jake the details over the phone and made an appointment to meet him the next day. In preparation for the meeting Jake used Hydro-Calc tool to prepare the following table:

Segment #	Length	Flow (gpm)	Pressure drop (psi)	Operating pressure (psi)
1	50'	1000	1.6	106.3
2	100'	900	2.6	104.7
3	100'	800	2.1	102.1
4	100'	700	1.7	100.0
5	100'	600	1.2	98.3
6	100'	500	0.9	97.1
7	100'	400	0.6	96.2
8	100'	300	0.3	95.6
9	100'	200	0.2	95.3
10	100'	100	<0.1	95.1

He created the table by first entering:

- 1000 in the input cell for Quantity of Flow in Gallons/minute
- 130 in the input cell for C, roughness coefficient
- 6 in the input cell for R, Pipe Diameter in inches

The calculated pressure drop for this first segment was 0.032 psi per foot (see Figure 22) which means the pressure drop for the 50-foot pipe segment is 1.6 psi (0.032*50).

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.

No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		2.22801	Cubic Feet/Sec
	Quantity of flow	1000	1000.00000	US Gallons/Minute
	Quantity of flow		0.06309	Cubic Meters/Sec
	Quantity of flow		3785.41200	Liters/Minute
V	Velocity of flow		11.34716	Feet/Sec
	Velocity of flow		3.45861	Meters/Sec
C	Roughness coefficient	130	130.00000	No Units
R	Hydraulic Radius (a/p)		0.12500	Feet
	Hydraulic Radius (a/p)		0.03810	Meters
	Pipe Diameter	6	6.00000	Inches
	Pipe Diameter		15.24000	Centimeters
S	Hydraulic slope		0.07419	Feet/Foot or Meter/Meter
	Pressure Drop		0.03216	Pounds/Square Inch/Foot
	Pressure Drop		22.61201	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 22

Jake calculated the next pipe segment, and each subsequent run of the pipe by changing the Quantity of flow:

- 900 in the input cell for Quantity of Flow in Gallons/minute
- 130 in the input cell for C, roughness coefficient
- 6 in the input cell for R, Pipe Diameter in inches

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.

No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		2.00521	Cubic Feet/Sec
	Quantity of flow	900	900.00000	US Gallons/Minute
	Quantity of flow		0.05678	Cubic Meters/Sec
	Quantity of flow		3406.87080	Liters/Minute
V	Velocity of flow		10.21244	Feet/Sec
	Velocity of flow		3.11275	Meters/Sec
C	Roughness coefficient	130	130.00000	No Units
R	Hydraulic Radius (a/p)		0.12500	Feet
	Hydraulic Radius (a/p)		0.03810	Meters
	Pipe Diameter	6	6.00000	Inches
	Pipe Diameter		15.24000	Centimeters
S	Hydraulic slope		0.06104	Feet/Foot or Meter/Meter
	Pressure Drop		0.02646	Pounds/Square Inch/Foot
	Pressure Drop		18.60386	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 23

The calculated pressure drop for this second segment was 0.026 psi per foot (see figure 23) which means the pressure drop for the 100-foot pipe segment is 2.6 psi (0.026*100)

Jake explained that the advice that John got from Jimmy Handley was a very common misconception even among engineers, but it was nonetheless, utterly wrong. The reason for stepping down the pipe sizes is merely to save money on the pipe material, but John, you got such a great deal on the 6” pipe that there is no point in changing sizes. By using one size pipe, you have minimized the total pressure loss in the system which is very desirable. You will be pumping at 106.3 psi to have 95 psi left at the last sprinkler. If you stepped down the pipe sizes, you would have to pump at a higher pressure or start with a pipe larger than 6” to accomplish the same thing. The only disadvantage to this system is that the velocity of water in the last segment or two may not be enough to keep the pipe clean. You can easily solve that problem by installing a clean-out on the far end of the system so you can flush the pipe every year or so. Maintaining a uniform pipe size also allows the option of using a “pig” to keep the line clean. Jake showed John a photograph of a football-shaped brush that can be inserted into the line at the pump end and pushed through the pipe with water pressure until it pops out through the clean-out.

His confidence restored, John installed the entire system himself and operated it just as Jake Akins had predicted. Jake wrote a paper about the project which he circulated to other farmers who were shopping for irrigation systems. He also made a point of sending it to all of the irrigation contractors in the area.

Sample Problem 7

The public water utility for a small city with a population 40,000 was forced to take drastic action when federal regulators found dangerous concentrations of contaminants in the lake that was the source of their water. There was no other source of water available within the city which left them with only one option. John Daugherty, the city's chief engineer, began negotiations to buy treated water from the regional utility who had a large water treatment plant and distribution system nearby.

John sat in a meeting with the engineers from the regional utility to work out the details of a plan. His first thought was to shut down the city plant and connect the city distribution system directly to the regional pipe network. It would require a new water transmission main 24,500 feet in length and capable of supplying 4-million gallons per day with a peak factor of 250%. He planned to use schedule 40 PVC with C=130 to speed the installation.

He quickly calculated the average flow to be 2778 gallons/minute and the peak to be 6944 gallons/minute. The pressure in the regional transmission line where they would connect was 65 pounds/square inch and the head loss in the new main could be no more than 10 pounds/square inch. John entered the numbers into Hydro-Calc tool on his laptop. The calculated value for diameter was 30.7 inches. Everyone agreed that that plan was not workable. (See Figure 24)

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.
No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		15.47130	Cubic Feet/Sec
	Quantity of flow	6944	6944.00000	US Gallons/Minute
	Quantity of flow		0.43810	Cubic Meters/Sec
	Quantity of flow		26285.90095	Liters/Minute
V	Velocity of flow		3.00397	Feet/Sec
	Velocity of flow		0.91561	Meters/Sec
C	Roughness coefficient	130	130.00000	No Units
R	Hydraulic Radius (a/p)		0.64019	Feet
	Hydraulic Radius (a/p)		0.19513	Meters
	Pipe Diameter		30.72924	Inches
	Pipe Diameter		78.05227	Centimeters
S	Hydraulic slope		0.00094	Feet/Foot or Meter/Meter
	Pressure Drop	0.000408163	0.00041	Pounds/Square Inch/Foot
	Pressure Drop		0.28697	Kilograms/Sq Meter/Meter

Inputs OK!

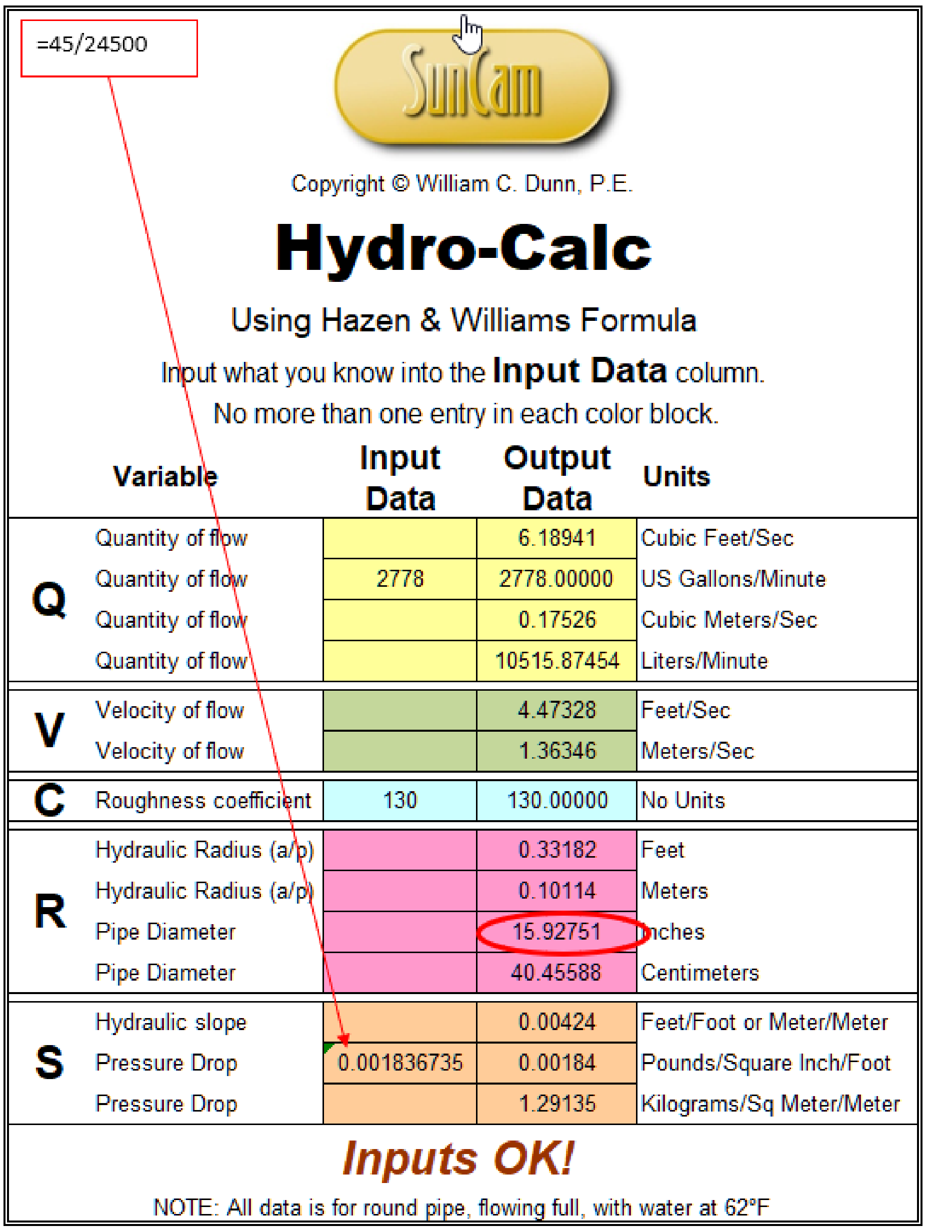
NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 24

The chief engineer for the regional utility spoke up and said that his plant would not have the capability of meeting the city's *peak* demand and suggested an alternative.

John would discontinue treating water at the city treatment plant and convert it exclusively to storage and distribution pumping. The city could take delivery of water into their reservoir at a constant 2778 gallons/minute at a pressure of 20 pounds per square inch (making the available head loss 45 psi). They could then pump the water into their distribution system using the city's high service pumps to meet their peak demand.

John plugged the numbers into Hydro-Calc. The calculated value for diameter was 15.93 inches. All agreed that they had a workable plan for a new 16-inch diameter PVC, low-pressure water transmission main. (See Figure 25)


=45/24500

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Hydro-Calc

Using Hazen & Williams Formula

Input what you know into the **Input Data** column.

No more than one entry in each color block.

	Variable	Input Data	Output Data	Units
Q	Quantity of flow		6.18941	Cubic Feet/Sec
	Quantity of flow	2778	2778.00000	US Gallons/Minute
	Quantity of flow		0.17526	Cubic Meters/Sec
	Quantity of flow		10515.87454	Liters/Minute
V	Velocity of flow		4.47328	Feet/Sec
	Velocity of flow		1.36346	Meters/Sec
C	Roughness coefficient	130	130.00000	No Units
R	Hydraulic Radius (a/p)		0.33182	Feet
	Hydraulic Radius (a/p)		0.10114	Meters
	Pipe Diameter		15.92751	Inches
	Pipe Diameter		40.45588	Centimeters
S	Hydraulic slope		0.00424	Feet/Foot or Meter/Meter
	Pressure Drop	0.001836735	0.00184	Pounds/Square Inch/Foot
	Pressure Drop		1.29135	Kilograms/Sq Meter/Meter

Inputs OK!

NOTE: All data is for round pipe, flowing full, with water at 62°F

Figure 25

Conclusion

For a century the Hazen-Williams formula has proven to be an accurate predictor of flow in pipes, and now the SunCam Hydro-Calc tool makes it easier to use that formula than ever before. It allows us to ask the probative questions, the “what-ifs” that make us better engineers.

So much of engineering design starts with making an informed guess followed by analysis of that guess. Having a tool that makes it possible to do that analysis effortlessly means that we are more likely to explore many more alternatives before we make a final decision. A device that helps us “tinker” with the inputs to problem-solving helps us understand the sensitivities of outputs to those inputs.

Our objective for this course has been to develop a better understanding of the flow of water in pipes and to give attendees a new tool for solving problems and answering questions.

A final word of caution about software. Never rely entirely on this or any software package to give you the final answers to engineering questions. Use it to optimize and explore but then crunch your own numbers to verify and cross-check results. Your professional integrity and the public’s health and safety are riding on it.

Appendix "A"

A sampling of Hazen Williams roughness coefficients:

Aluminum	130-150
Asbestos-Cement	140-160
Cast Iron (new)	100-140
Cast Iron (Old)	60-110
Cement Lined Ductile Iron	120
Concrete	100-140
Copper	130-140
Corrugated Metal	60
Fiber-Reinforced Plastic	150
Galvanized	120
Polyethylene	140
PVC	120-150
Steel	90-120