

PipeCalc4c

Pipe calculator for partial flow

for the HP Prime Calculator

2/7/2026 by E Shiimoto

This HP Prime calculator program can numerically solve for the unknown variable for Manning $n=\text{constant}$, Manning $n=f(D)$, Colebrook, $Q=VA$, and other equations for a circular pipe flowing partially full. The results are displayed on the calculator's print terminal. To switch programs, select the new program from the Menu on the INPUT screen and press the OK tab. To rerun the same program, press the Esc key to exit the terminal, and press the Enter key to rerun the program. For educational use.

The Menu box is used to change programs. To change the program, select a new program from the list and press the OK tab.

- 1 Manning Flowrate Eq $n=\text{const}$
- 2 Manning Velocity Eq $n=\text{const}$
- 3 Manning Flowrate Eq $n=f(D)$
- 4 Manning Velocity Eq $n=f(D)$
- 5 Colebrook Flowrate Eq
- 6 Colebrook Velocity Eq
- 7 S-min program
- 8 $Q=VA$ Eq
- 9 Critical Flow Eq
- 10 Shear Stress Eq
- 11 Raths-McCauley sand particle
- 12 $Q/Q_f \propto y/D$ Conversions
- 13 Q Conversions
- 14 Set no. of digits

Q low inputs and diameter rounding settings are shown on the second page of the input screen. These options are only available for the Manning and Colebrook flowrate programs.

Current program in use

1 Manning Flowrate Eq $n=\text{const}$ 09:40

Menu: 1 Manning Flowrate Eq $n=\text{const}$

n 0.013

Q 54.397 ft³/s

S 0.008

D 36 in

y/D 0.75 temp 60° F

Solve: Q

To change programs, select program & press OK

Choose Page 1/2 Cancel OK

1 Manning Flowrate Eq $n=\text{const}$ 08:31

Separate Q low calcs for V, τ (optional) ☐

Q low 0 % of Q 0

y/D low 0

Diameter rounding parameters for D↑ ☐

y/D max for pipe sizing (0.1 to 1) 1

dia list US Storm (in)

min dia row no. 2

not used

✓ Page 2/2 Cancel OK

n
Q
S
D
y/D
D↑, y/D given n Q S
clear inputs
clear terminal
view terminal
view pipe diameter list

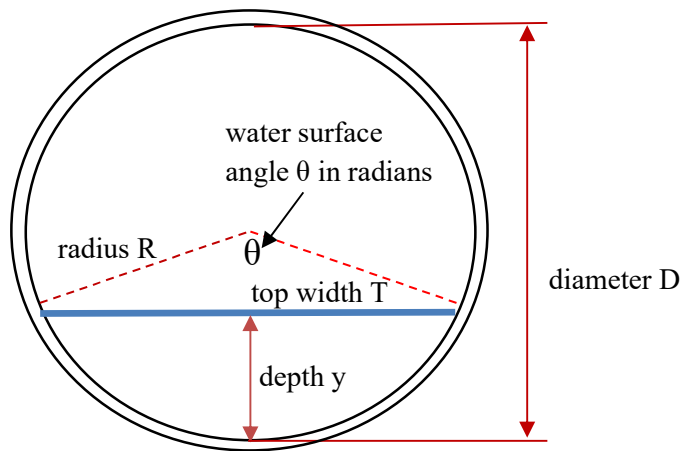
To solve for the unknown variable, input the known values and units. Select the variable to be solved from the Solve menu. Then, press the OK tab.

If the solve variable has units, select the units to be use.

The results will be displayed on the print terminal.

To run the program again, press the Esc key to exit the print terminal. Then, press the Enter key to run the program.

US Storm (in)
US Storm (soft metric rnd 5mm)
US Storm (soft metric rnd 10mm)
US Sewer (in)
US Sewer (soft metric rnd 5mm)
US Sewer (soft metric rnd 10mm)
US all dia (in)
US all dia (soft metric rnd 5mm)
US all dia (soft metric rnd 10mm)
US RCP (in)
US VCP (in)
US Gravity Drain PVC 1 (in)
US Gravity Drain PVC 2 (in)
US ADS HDPE (in)
UK Composite (mm)
Aus Composite (mm)
Aus RCP Class 4 (mm)
Ger Composite (mm)



Contents

1. Instructions	3
2. Solve for the unknown variable	6
3. Low flow calculations for $Q_{\min}$ or Q_{low}	7
4. Sizing a pipe using chain calculations	9
5. Sizing a pipe using the $D \uparrow$ auto sizing.....	11
6. Size a pipe for $y/D \text{ max} = 0.75$ using the $D \uparrow$ auto sizing	12
7. Solve S, D for $\tau \text{ min}$ (approx. method).....	13
8. Solve $S, y/D$ for $\tau \text{ min}$	15
9. Solving for S, D for $V_{\min}$	16
10. Q Conversion example.....	21
11. Revisions.....	22
12. Program comments	22

1. Instructions

Calculator System Settings and Operations

At the start of the program, the calculator will change the app angle mode to radians, the Home number format to floating with 4 digits (default), and the App number format to 0 for “use Home format settings”. At the end of the program, the calculator will restore the previous angle mode and number formats. The number of digits can be changed using program *Set no. of digits* program.

After the program solves for the unknown variable, the results are displayed on the calculator’s print terminal. When the program is run a second time, the results are added to the bottom of the print terminal. On a G1 calculator, the print terminal can hold about 100 lines of text. To view the print terminal, select *view terminal* from the *Solve* menu on the INPUT screen, and press the OK tab.

This program was used with software version 2.4, software build date 2025-09-15, and software revision 15515.

This program was written with the “period” used as the decimal separator, and will not work when the “comma” is used as the decimal separator.

The program size is 607 KB. The program will run on a G1 physical calculator, but the program cannot be edited on the physical calculator. However, the program can be edited on the virtual calculator.

Changing Programs

The name of the current program is displayed in the title of the input screen. To switch between the various programs, select the new program from the “Menu” choose list and then tap the OK tab located in the lower right corner of the screen. The input screen of the new program will display the input values and units from the previous program, if applicable.

Rerun the program

When the program ends, the print terminal is displayed with the calculated results. To rerun the program, press the Esc key to exit the print terminal, then press the Enter key to run the program. Another way to rerun the program is to press the Enter key twice. Alternatively, the program can be launched by pressing the Toolbox key, and then pressing the User tab, and the selecting PipeCalc.

When the program is run a second time, the program will run the last program that was used. The previous input entries and unit selections are displayed to facilitate chain calculations.

Clear Inputs

To clear the previous inputs, select “clear inputs” from the Solve input box, and press the OK tab. “Clear inputs” does not change the previous unit selections, diameter rounding parameters for $D_{\uparrow}$, or temperature settings.

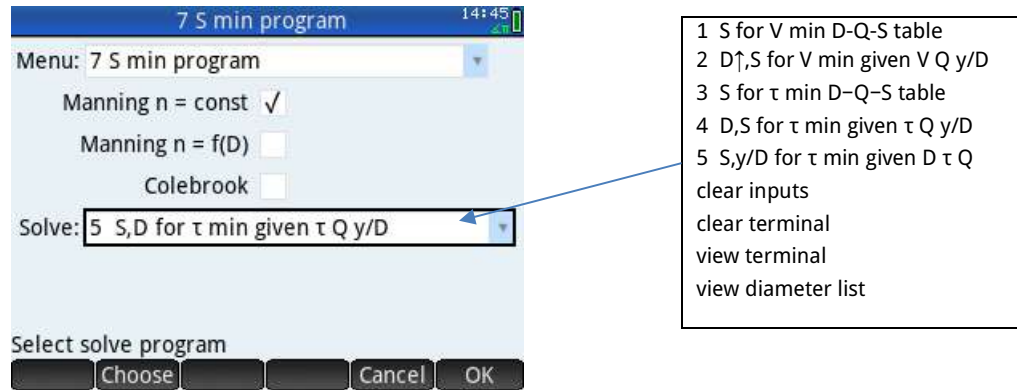
Exit the program

To exit the program from the input screen, press the Cancel tab on the input screen, or press the Esc key.

To exit the print terminal and return to the Home screen, press the Esc key or press the Home key.

S min program

One of the programs in PipeCalc is the “S min program”. This program allows the user to run a set of minimum slope programs for either $V_{\min}$ or $\tau_{\min}$ for the Manning $n=\text{const}$, Manning $n=f(D)$, and Colebrook equations.



Set no. of digits program

This program allows the user to set the number of digits displayed on the input screen and printed on the print terminal.

Temperature setting

The Manning and Colebrook flowrate and velocity programs include a temperature setting. This setting includes both Fahrenheit and Celsius temperatures. For the Colebrook equation, the temperature is used to determine the kinematic viscosity and density¹. For the Manning equation, the temperature is used to determine the equivalent roughness k_s .

Manning and Colebrook equations

This program calculates Manning’s equation in SI units, where the Manning k constant is the exact value of 1. The program then converts the values to English units, as necessary. Because of this, the program’s results will be slightly different from programs that use a rounded Manning’s k value of 1.49 or 1.486

Manning equations for partial flow in a circular conduit

$$\theta = 2 * \arccos \left(1 - 2 * \frac{y}{D} \right), \text{ where } \theta \text{ is in radians. } y \text{ is the depth. See footnote}^2$$

$$V = \frac{k D^{2/3} S^{1/2} (\theta - \sin(\theta))^{2/3}}{2^{4/3} N \theta^{2/3}}, \text{ where } k=1 \text{ for metric calculations}$$

¹ The kinematic viscosity and density values used in PipeCalc4c were taken from *Table A.8 Properties of water in English units* and *Table A.9 Properties of water in SI Metric units*, Water Supply and Pollution Control, 5th Ed., by W Viessman, Jr and MJ Hammer, HarperCollins College Publishers, 1993, p846. For density, $1 \frac{\text{slug}}{\text{ft}^3} = 1 \frac{\text{lb} \cdot \text{s}^2}{\text{ft}^4}$.

² Water-Resources Engineering, 3rd Ed., Pearson, 2013 by David Chin, page 222, example 6.4. Also, in *Urban Drainage*, by D Butler and JW Davies, 3rd Ed., Spon Press, UK, 2011, equation 8.17 and figure 8.7 on page 162.

$$Q = \frac{k D^{8/3} S^{1/2} (\theta - \sin(\theta))^{5/3}}{2^{13/3} N \theta^{2/3}}, \text{ where } k=1 \text{ for metric calculations, see footnote}^3$$

There are several versions of the Colebrook-White equation. This program uses the version with the 3.71 and 2.51 constants. Further, there are two versions of the Colebrook velocity equation for partial flow. One version is expressed in terms of R_h , and the other is expressed in terms of ΨD . PipeCalc had initially used the R_h version, but was later changed to use the ΨD version.

Colebrook-White equation for full flow

$$\frac{1}{\sqrt{\lambda}} = -2 \log_{10} \left(\frac{k_s}{3.71 D} + \frac{2.51}{Re \sqrt{\lambda}} \right) \quad \text{See footnote}^4$$

Colebrook velocity equation for full flow in a circular conduit

$$V = -2 \sqrt{2 g S D} \log_{10} \left(\frac{k_s}{3.71 D} + \frac{2.51 \nu_k}{D \sqrt{2 g S D}} \right) \quad \text{See footnote}^5$$

Colebrook velocity equations for partial flow in a circular conduit

$$V = -(32 g R_h S)^{0.5} \log_{10} \left(\frac{k_s}{14.84 R_h} + \frac{1.255 \nu_k}{R_h (32 g R_h S)^{0.5}} \right) \quad R_h \text{ format. See footnote}^6$$

$$\Psi = \frac{(\theta - \sin \theta)}{\theta} \quad \text{See footnote}^7$$

$$V = -2 \sqrt{2 g S \Psi D} \log_{10} \left(\frac{k_s}{3.71 \Psi D} + \frac{2.51 \nu_k}{\Psi D \sqrt{2 g S \Psi D}} \right) \quad \Psi D \text{ format. See footnote}^8$$

³ This equation is algebraically equivalent to the Manning flowrate equation (constant n) in *Water-Resources Engineering*, 3rd Ed., Pearson, 2013 by David Chin, page 218. Note that the $2^{13/3}$ constant is equal to the 20.16 constant used in *Water-Resources Engineering*.

⁴ Colebrook-White friction equation for full flow from *Tables for the Hydraulic Design of Pipes, Sewers and Channels*, 7th Ed, Vol 1, by HR Wallingford and DIH Barr, Thomas Telford London, UK, 1998, equation 3, page 4. Also, from *Urban Drainage* by D Butler and JW Davies, 3rd Ed., Spon Press, UK, 2011, equation 8.9, page 154, except that a 3.71 constant is shown here, instead of a 3.7 constant.

⁵ Colebrook velocity equation for full flow from *Urban Drainage*, by D Butler and JW Davies, 3rd Ed., Spon Press, UK, 2011, equation 8.10 on page 154, except that a 3.71 constant is shown here, instead of a 3.7 constant. ν_k is the kinematic viscosity. Also, this equation is shown in *Drain and sewer systems outside buildings – Design, part 2: Hydraulic Design*, European Standard, BS EN 16933-2:2017, equation 1, page 12. Further, this equation is algebraically equivalent to the Colebrook velocity equation in *Tables for the Hydraulic Design of Pipes, Sewers and Channels*, 7th Ed, Vol 1, by HR Wallingford and DIH Barr, Thomas Telford London, UK, 1998, equation 7, page 4.

⁶ Colebrook velocity equation for partial flow from *Design charts for water supply and sewerage*, Australian Standard. AS 2200-2006 (incorporating amendment no. 1), except that a 14.84 constant is shown above, instead of a 14.8 constant. A flowrate version of the equation for partial flow is shown in *Applicability of the Colebrook-White Formula to Represent Frictional Losses in Partially Filled Unsteady Pipeflow*, by JA Swaffield and S Bridge, Journal of Research of the National Bureau of Standards UK, Vol. 88, No. 6, Nov-Dec 1983, except that 14.84 and 2.51 constants are shown above, instead of 14.83 and 2.52 constants.

⁷ Shape correction factor for partial flow from *Urban Drainage*, by D Butler and JW Davies, 3rd Ed., Spon Press, UK, 2011, equation 8.19 on page 166.

⁸ Colebrook velocity equation for partial flow from *Urban Drainage*, by D Butler and JW Davies, 3rd Ed., Spon Press, UK, 2011, equation 8.19 on page 166, except that a 3.71 constant was used instead of a 3.7 constant. ν_k is the kinematic viscosity.

Program background

PipeCalc was written as a replacement for the Field's Hydraulic Calculator and the HP-41 Pipe Slide-Rule program.

2. Solve for the unknown variable

In general, you can solve for any one variable of an equation on PipeCalc, provided the other variables are known. Simply, run PipeCalc. Switch to the desired equation. Enter the values and units of the known variables. Specify the variable to be solved in the "Solve" box. If the solve variable has units, specify the units of the solve variable. Finally, press the OK tab located in the lower right corner of the screen. The program will solve for the unknown variable and display the results on the print terminal.

Problem

Determine the discharge rate in a 24 in concrete pipe on a slope of 0.008 that has a relative depth of $y/D = 0.45$. (Use the Manning equation and assume $n = 0.014$ for a concrete pipe)

To switch to the "Manning Flowrate Eq $n=\text{const}$ " program, select "Manning Flowrate Eq $n=\text{const}$ " in menu box, and press the OK tab.

On the input screen for the Manning flowrate equation, the variables n , Q , S , D , and y/D are displayed. Note that input variables Q and D have units. Below the input variables is a "Solve" drop box that list all of the variables. There is a water temperature box near the lower right corner of the input screen, that is used to determine the equivalent k_s value. The input screen second page has optional inputs for low flowrates and diameter rounding that are not used in this example. The second page of the input screen is only used in the Manning Flowrate Eq $n=\text{const}$, Manning Flowrate Eq $n=f(D)$, and Colebrook Flowrate Eq programs.

In this problem, n , S , D , and y/D are the known variables, and Q is the unknown variable.

Enter the value and units of the known variables. When solving for Q , you need to enter the units of Q . In the solve box, select Q . Finally, press the OK tab located in the lower right-hand corner.

Input screen for Manning Flowrate Eq $n=\text{const}$

Menu: 1 Manning Flowrate Eq $n=\text{const}$		Separate Q low calcs for V, τ (optional)	
n:	0.014	Q low ☐ 0	% of Q ☐ 0
Q:	0 ft ³ /s	y/D low ☐ 0	
S:	0.008	Diameter rounding parameters for $D^\uparrow$	
D:	24 in	y/D max for pipe sizing (0.1 to 1): 1	
y/D:	0.45	dia list: US Storm (in)	
temp	60° F	min dia row no.: 2	
Solve:	Q		

The calculator indicates the flowrate $Q = 7.8257 \text{ ft}^3/\text{s}$.

Print Terminal

```
----- PipeCalc4c -----
01 Manning Flowrate Eq n=const
02 Solve: Q
  ▶ Manning n = 0.014
    flowrate Q = 7.8257_(ft^3/s)★
  ▶ slope S = 0.008
    slope ratio = 1 : 125
  ▶ diameter D = 24_in
  ▶ relative depth y/D = 0.45
    depth y = 10.8_in
    central angle  $\theta$  = 2.9413_rad
  ▶ water temp = 60° F
  ---
    velocity V = 5.7075_(ft/s)
    ave shear stress  $\tau$  = 0.23257_(lbf/ft^2)
    froude no. = 1.2122
    (equivalent ks = 2.5359_mm)
```

```
area A = 1.3711_ft^2
hydraulic radius Rh = 0.46617_ft
wetted perimeter P = 2.9413_ft
top width T = 1.99_ft
Q full = 18.788_(ft^3/s)  y/D = 1 & 0.81963
Q peak = 20.21_(ft^3/s)  y/D = 0.93818
V full = 5.9803_(ft/s)  y/D = 1 & 0.5
V peak = 6.8178_(ft/s)  y/D = 0.8128
critical rel. depth (y/D crit) = 0.49766
critical depth (y crit) = 11.944_in
kinematic viscosity  $\nu_k$  = 12.170E-6_(ft^2/s)
density  $\rho$  = 1.9383E0_(slug/ft^3)
Notes
• The calculation of  $\tau$  uses the approximate
equation, where  $\sin(\theta)=S$ .
```

3. Low flow calculations for $Q_{\min}$ or Q_{low}

PipeCalc can perform separate or secondary calculations for $Q_{\min}$ or Q_{low} on the Manning Flowrate $n=\text{const}$, Manning Flowrate $n=f(D)$, and Colebrook Flowrate programs. This is done by inputting $Q_{\min}$ or Q_{low} on the second page of the input screen.

There are three ways to enter $Q_{\min}$: 1) by entering the value of $Q_{\min}$, 2) by entering the percent of Q , where the program will calculate $Q_{\min} = \text{percentage} * Q$, or 3) by entering the relative depth y/D .

Example of the “Q low” input

For a 24 in diameter pipe at a slope of 0.10 feet per hundred with a pipe roughness of $n = 0.013$, determine the depth of flow and velocity for the following flowrates: $Q_{\text{max}} = 3.9$ MGD and $Q_{\text{min}} = 0.9$ MGD.

Input screen for Manning Flowrate Eq $n=\text{const}$

```
Menu: 1 Manning Flowrate Eq n=const
n: 0.013
Q: 3.9 MGD
S: 0.001
D: 24 in
y/D: 0 temp 70° F
Solve: y/D
```

```
Separate Q low calcs for V,  $\tau$  (optional)
Q low ☒ 0.9 % of Q ☐ 0
y/D low ☐ 0
Diameter rounding parameters for D↑
y/D max for pipe sizing (0.1 to 1): 1
dia list: US Storm (in)
min dia row no.: 2
```

Print Terminal

```

----- PipeCalc4c -----
01 Manning Flowrate Eq n=const
05 Solve: y/D
  ▷ Manning n = 0.013
  ▷ flowrate Q = 3.9_(MgalUS/d)
  ▷ slope S = 0.001
    slope ratio = 1 : 1000
  ▷ diameter D = 24_in
    relative depth y/D = 0.70404 ★
    depth y = 16.897_in
    central angle  $\theta$  = 3.9823_rad
  ▷ water temp = 70° F
  ---
  velocity V = 2.5528_(ft/s)
  ave shear stress  $\tau$  = 0.03688_(lbf/ft²)
  froude no. = 0.39556
  (equivalent ks = 1.3795_mm)
  area A = 2.3637_ft²
  hydraulic radius Rh = 0.59355_ft
  
```

```

wetted perimeter P = 3.9823_ft
top width T = 1.8259_ft
Q low calcs for Q low = 0.9_(MgalUS/d)
V low = 1.7643_(ft/s)
 $\tau$  low = 0.02119_(lbf/ft²)
y/D low = 0.29907
y low = 7.1778_in
Q full = 4.6234_(MgalUS/d) y/D = 1 & 0.81963
Q peak = 4.9734_(MgalUS/d) y/D = 0.93818
V full = 2.277_(ft/s) y/D = 1 & 0.5
V peak = 2.5959_(ft/s) y/D = 0.8128
critical rel. depth (y/D crit) = 0.43441
critical depth (y crit) = 10.426_in
kinematic viscosity  $\nu_k$  = 10.590E-6_(ft²/s)
density  $\rho$  = 1.9310E0_(slug/ft³)
Notes
• The calculation of  $\tau$  uses the approximate
equation, where  $\sin(\theta)=S$ .
  
```

Example of the “percent of Q” input

For a 450 mm diameter pipe at a slope of 0.005 with a pipe roughness of $ks = 1.5$ mm, determine the depth of flow and velocity for a design flowrate of 170 l/s. Also, determine the depth of flow and velocity at 1/3 of the design flowrate.⁹

Input screen for Colebrook Flowrate Eq

```

Menu: 5 Colebrook Flowrate Eq
ks: 1.5 mm
Q: 170 l/s
S: 0.005
D: 450 mm
y/D: 0 temp 20° C
Solve: y/D
  
```

```

Separate Q low calcs for V,  $\tau$  (optional)
Q low ☐ 0 % of Q ☒ 33.33
y/D low ☐ 0
Diameter rounding parameters for D↑
y/D max for pipe sizing (0.1 to 1): 1
dia list: US Storm (in)
min dia row no.: 2
  
```

⁹ In *Design and Construction Guidance* for water and sewerage companies operating in England, dated May 25, 2021, storm lines are recommended to be designed for full flow (section C6.4.3) using $ks = 0.6$ mm (section C6.4.2). To provide self-cleaning of storm lines, the minimum velocity should be 1 m/s at full flow (section C7.2.3.3). Sewer lines are recommended to be designed with y/D max = 0.75 (section B3.1.4) using $ks = 1.5$ mm for all pipe materials (section B3.1.3). To provide self-cleaning of sewer lines, the minimum velocity should be 0.75 m/s at 1/3 of the design flowrate (section B6.9).

Print Terminal

```
----- PipeCalc4c -----
05 Colebrook Flowrate Eq
05 Solve: y/D
  ▸ roughness ks = 1.5_mm
  ▸ flowrate Q = 170_(l/s)
  ▸ slope S = 0.005
    slope ratio = 1 : 200
  ▸ diameter D = 450_mm
    relative depth y/D = 0.70301 ★
    depth y = 316.36_mm
    central angle  $\theta$  = 3.9778_rad
  ▸ water temp = 20° C
  ---
    velocity V = 1.4229_(m/s)
    ave shear stress  $\tau$  = 6.5336_Pa
    froude no. = 0.84301
    (equivalent n = 0.01298)
    area A = 0.11947_m^2
    hydraulic radius Rh = 0.13349_m
    wetted perimeter P = 0.89501_m
```

```
top width T = 0.41124_m
Q low calcs for % of Q = 33.33%
  Q low = 56.661_(l/s)
  V low = 1.0962_(m/s)
   $\tau$  low = 4.363_(N/m^2)
  y/D low = 0.36072
  y low = 162.32_mm
Q full = 202.72_(l/s)  y/D = 1 & 0.82392
Q peak = 217.33_(l/s)  y/D = 0.93976
V full = 1.2746_(m/s)  y/D = 1 & 0.5
V peak = 1.4464_(m/s)  y/D = 0.8128
critical rel. depth (y/D crit) = 0.64409
critical depth (y crit) = 289.84_mm
kinematic viscosity  $\nu_k$  = 1.0030E-6_Pa
density  $\rho$  = 998.20E0_(kg/m^3)
Notes
  • The calculation of  $\tau$  uses the approximate
    equation, where  $\sin(\theta)=S$ .
```

4. Sizing a pipe using chain calculations

PipeCalc supports successive chain calculations. The program will retain the last values of the known and solved variables. (On the HP-41 Pipe Slide Rule, the previous input values were not saved, and one had to reenter the inputs every time the program was run.)

Problem

Size a storm pipe to handle a flow rate of 18.6 cfs, where roughness $n = 0.013$ and a slope $S = 0.0015$. Determine the velocity of flow.

answer: $D = 36$ in, $y/D = 0.62832$, depth $y = 22.62$ in, and velocity $V = 3.9774$ ft/s.

For this problem, the Manning equation is used twice: 1) to solve for the calculated diameter, where the calculated diameter is manually rounded up, and 2) to solve for the relative depth y/D and velocity.

Run the PipeCalc program. Switch to the Manning Flow Equation program by selecting the Manning Flow Eq from the menu and then press the OK tab.

1) Solve for the diameter

Input screen for Manning Flowrate Eq $n=\text{const}$

```
Menu: 1 Manning Flowrate Eq n=const
n: 0.013
Q: 18.6 ft^3/s
S: 0.0015
D: 0 in
y/D: 1 temp 60° F
Solve: D
```

```
Separate Q low calcs for V,  $\tau$  (optional)
  Q low ☐ 0 % of Q ☐ 0
  y/D low ☐ 0
Diameter rounding parameters for D↑
y/D max for pipe sizing (0.1 to 1): 1
dia list: US Storm (in)
min dia row no.: 2
```

Print Terminal

```
----- PipeCalc4c -----
01 Manning Flowrate Eq n=const
04 Solve: D
  > Manning n = 0.013
  > flowrate Q = 18.6_(ft^3/s)
  > slope S = 0.0015
    slope ratio = 1 : 666.67
    diameter D = 31.829_in*
  > relative depth y/D = 1
    depth y = 31.829_in
    central angle  $\theta$  = 6.2832_rad
  > water temp = 60° F
  ---
    velocity V = 3.3663_(ft/s)
    ave shear stress  $\tau$  = 0.06203_(lbf/ft^2)
    froude no. = not applic.
    (equivalent ks = 1.3424_mm)
```

```
area A = 5.5254_ft^2
hydraulic radius Rh = 0.6631_ft
wetted perimeter P = 8.3327_ft
top width T = not applic.
Q full = 18.6_(ft^3/s)  y/D = 1 & 0.81963
Q peak = 20.008_(ft^3/s)  y/D = 0.93818
V full = 3.3663_(ft/s)  y/D = 1 & 0.5
V peak = 3.8376_(ft/s)  y/D = 0.8128
critical rel. depth (y/D crit) = 0.54114
critical depth (y crit) = 17.224_in
kinematic viscosity  $\nu_k$  = 12.170E-6_(ft^2/s)
density  $\rho$  = 1.9383E0_(slug/ft^3)
Notes
• The calculation of  $\tau$  uses the approximate
equation, where  $\sin(\theta)=S$ .
```

Round the pipe diameter upwards to 36 in.

2) Solve for the relative depth y/D

Rerun PipeCalc and solve for the depth of flow using the rounded diameter of 36 inch.

PipeCalc can be rerun by pressing the Esc key to exit the print terminal, and pressing the Enter key to rerun the program. The program's input screen will display the last values and units.

Input screen for Manning Flowrate Eq n=const

```
Menu: 1 Manning Flowrate Eq n=const
n: 0.013
Q: 18.6 ft^3/s
S: 0.0015
D: 36 in
y/D: 1 temp 60° F
Solve: y/D
```

Separate Q low calcs for V, τ (optional)

```
Q low ☐ 0 % of Q ☐ 0
y/D low ☐ 0
Diameter rounding parameters for D↑
y/D max for pipe sizing (0.1 to 1): 1
dia list: US Storm (in)
min dia row no.: 2
```

Print Terminal

```
----- PipeCalc4c -----
01 Manning Flowrate Eq n=const
05 Solve: y/D
  > Manning n = 0.013
  > flowrate Q = 18.6_(ft^3/s)
  > slope S = 0.0015
    slope ratio = 1 : 666.67
  > diameter D = 36_in
    relative depth y/D = 0.62832*
    depth y = 22.62_in
    central angle  $\theta$  = 3.6607_rad
  > water temp = 60° F
  ---
    velocity V = 3.9774_(ft/s)
    ave shear stress  $\tau$  = 0.07967_(lbf/ft^2)
    froude no. = 0.55215
    (equivalent ks = 1.2472_mm)
```

```
area A = 4.6764_ft^2
hydraulic radius Rh = 0.85164_ft
wetted perimeter P = 5.491_ft
top width T = 2.8995_ft
Q full = 25.831_(ft^3/s)  y/D = 1 & 0.81963
Q peak = 27.786_(ft^3/s)  y/D = 0.93818
V full = 3.6543_(ft/s)  y/D = 1 & 0.5
V peak = 4.166_(ft/s)  y/D = 0.81281
critical rel. depth (y/D crit) = 0.4606
critical depth (y crit) = 16.581_in
kinematic viscosity  $\nu_k$  = 12.170E-6_(ft^2/s)
density  $\rho$  = 1.9383E0_(slug/ft^3)
Notes
• The calculation of  $\tau$  uses the approximate
equation, where  $\sin(\theta)=S$ .
```

5. Sizing a pipe using the D↑ auto sizing

The D↑ auto sizing option is only available on the Manning and Colebrook flowrate equations. D↑ means solve for the diameter and round upwards based on a predefined diameter list, and then solve for the actual depth. To use the D↑ option, the diameter rounding parameters on page 2 of the input screen must be specified.

Predefined diameter lists

The D↑ auto sizing option rounds the calculated diameter based on a predefined diameter list. The diameter lists used in PipeCalc include both the inside and nominal diameters. For most diameter lists, the inside diameter equals the nominal diameters. However, for some pipes, the inside diameter can be different from its nominal diameter, such as in the *US gravity drain PVC 1 and 2*, and the *Aus RCP CI-4 (mm)* diameter lists. These diameter lists were added for testing purposes.

The *US Storm (in)* diameter list does not contain a 21", 27", 33" and 39" diameters. The *US Sewer (in)* diameter list does not contain a 33" and 39" diameters.

The program contains soft metric versions of the *US Storm (in)*, *US Sewer (in)*, and *US all dia (in)* diameter lists. For the US "soft metric" diameter lists, the inside diameter and nominal diameters are in millimeters.

PipeCalc can perform mix unit calculations. So, one can use the D↑ auto sizing option for metric calculation with the *US Storm (in)* diameter list.

Viewing the pipe diameter lists

The diameter lists can be viewed by setting solve to "view pipe diameter list" and then pressing the OK tab. Then, on the "view pipe diameter list" input screen, select "US Composite in" and press the OK tab. The diameter list will be printed on the print terminal. Row no. 2 always represents the smallest diameter on the diameter list.

The pipe diameter lists can only be viewed on the flowrate programs.

----- PipeCalc4c -----		
Diameter List = US Gravity Drain PVC 2 (in)		
where row 1 = units		
row	Actual ID	Nominal Dia
1	1_in	SDR-26, PS-115
2	3.891	4
3	5.793	6
4	7.754	8
5	9.692	10
6	11.538	12
7	14.124	15
8	17.261	18
9	20.349	21
10	22.891	24
...		

Example of the D↑ auto sizing

Size a storm pipe for full flow, given $S = 0.0015$, $Q = 18.6$ cfs, and $n = 0.013$.

For this problem, Solve is set to D↑,y/D given n Q S , and set y/D max to 1 for full flow. The diameter list is set to *US Storm (in)*. The minimum diameter row number is set to 2, which represents the smallest diameter in the diameter list. Enter n, Q and S.

Input screen for Manning Flowrate Eq $n = \text{const}$

Menu: 1 Manning Flowrate Eq $n = \text{const}$	Separate Q low calcs for V, τ (optional)
n: 0.013	Q low ☐ 0 % of Q ☐ 0
Q: 18.6 ft ³ /s	y/D low ☐ 0
S: 0.0015	Diameter rounding parameters for D↑
D: 0 in	y/D max for pipe sizing (0.1 to 1): 1
y/D: 0 temp 60° F	dia list: US Storm (in)
Solve: D↑, y/D given n Q S	min dia row no.: 2

Print Terminal

<pre> ----- PipeCalc4c ----- 01 Manning Flowrate Eq n=const 06 Solve: D↑, y/D given n Q S ▷ Manning n = 0.013 ▷ flowrate Q = 18.6_(ft^3/s) ▷ slope S = 0.0015 slope ratio = 1 : 666.67 nominal diameter D = 36_in ★ inside diameter ID = 36_in (calculated diameter = 31.829_in) ▷ y/D max for pipe sizing = 1 ▷ dia. list = US Storm (in) ▷ minimum diameter row no. = 2 minimum diameter = 4_in relative depth y/D = 0.62832 ★ depth y = 22.62_in central angle $\theta = 3.6607_{\text{rad}}$ ▷ water temp = 60° F --- velocity V = 3.9774_(ft/s) ave shear stress $\tau = 0.07967_{\text{(lbf/ft}^2\text{)}}$ </pre>	<pre> froude no. = 0.55215 (equivalent ks = 1.2472_mm) area A = 4.6764_ft^2 hydraulic radius Rh = 0.85164_ft wetted perimeter P = 5.491_ft top width T = 2.8995_ft Q full = 25.831_(ft^3/s) y/D = 1 & 0.81963 Q peak = 27.786_(ft^3/s) y/D = 0.93818 V full = 3.6543_(ft/s) y/D = 1 & 0.5 V peak = 4.166_(ft/s) y/D = 0.81281 critical rel. depth (y/D crit) = 0.4606 critical depth (y crit) = 16.581_in kinematic viscosity $\nu_k = 12.170\text{E-}6_{\text{(ft}^2\text{/s)}}$ density $\rho = 1.9383\text{E}0_{\text{(slug/ft}^3\text{)}}$ Notes • The calculation of τ uses the approximate equation, where $\sin(\theta) = S$. </pre>
--	--

6. Size a pipe for $y/D \text{ max} = 0.75$ using the D↑ auto sizing

Size a pipe to handle 83 l/s under gravity flow, where $y/D \text{ max} = 0.75$ and the available slope is 0.006. V_{min} at 1/3 the design flow = 0.75 m/s.¹⁰ Use $ks = 1.5 \text{ mm}$.

To input Q_{min} , check “% of Q”, and input 33.33. The program will calculate Q_{min} to be 1/3 of Q.

To input $y/D \text{ max}$, set “y/D max for pipe sizing” to 0.75.

Input screen for Colebrook Flowrate Eq

Menu: 5 Colebrook Flowrate Eq	Separate Q low calcs for V, τ (optional)
ks: 1.5 mm	Q low ☐ 0 % of Q ☒ 33.33
Q: 83 l/s	y/D low ☐ 0
S: 0.006	Diameter rounding parameters for D↑
D: 0 mm	y/D max for pipe sizing (0.1 to 1): 0.75
y/D: 0 temp 15° C	dia list: UK Composite (mm)
Solve: D↑, y/D given ks Q S	min dia row no.: 2

¹⁰ In Design and Construction Guidance for water and sewerage companies operating in England, dated May 25, 2021, sewer lines are recommended to be designed with $y/D \text{ max} = 0.75$ (section B3.1.4) using $ks = 1.5 \text{ mm}$ for all pipe materials (section B3.1.3). To provide self-cleaning of sewer lines, the minimum velocity should be 0.75 m/s at 1/3 of the design flowrate (section B6.9).

Print Terminal

```
----- PipeCalc4c -----
05 Colebrook Flowrate Eq
06 Solve: D↑, y/D given ks Q S
  ▸ roughness ks = 1.5_mm
  ▸ flowrate Q = 83_(l/s)
  ▸ slope S = 0.006
    slope ratio = 1 : 166.67
    nominal diameter D = 375_mm★
    inside diameter ID = 375_mm
    (calculated diameter = 321.74_mm)
  ▸ y/D max for pipe sizing = 0.75
  ▸ dia. list = UK Composite (mm)
  ▸ minimum diameter row no. = 2
    minimum diameter = 100_mm
    relative depth y/D = 0.56204★
    depth y = 210.77_mm
    central angle  $\theta$  = 3.3904_rad
  ▸ water temp = 15° C
  ---
    velocity V = 1.2984_(m/s)
    ave shear stress  $\tau$  = 5.9116_Pa
    froude no. = 1.0003
    (equivalent n = 0.0129)
```

```
area A = 0.06393_m^2
hydraulic radius Rh = 0.10056_m
wetted perimeter P = 0.6357_m
top width T = 0.3721_m
Q low calcs for % of Q = 33.33%
Q low = 27.664_(l/s)
V low = 0.97452_(m/s)
 $\tau$  low = 3.8099_(N/m^2)
y/D low = 0.30403
y low = 114.01_mm
Q full = 137.03_(l/s) y/D = 1 & 0.82316
Q peak = 146.99_(l/s) y/D = 0.9395
V full = 1.2407_(m/s) y/D = 1 & 0.5
V peak = 1.409_(m/s) y/D = 0.8128
critical rel. depth (y/D crit) = 0.56213
critical depth (y crit) = 210.8_mm
kinematic viscosity  $\nu_k$  = 1.1390E-6_Pa
density  $\rho$  = 999.10E0_(kg/m^3)
Notes
• The calculation of  $\tau$  uses the approximate
equation, where  $\sin(\theta)=S$ .
```

7. Solve S,D for τ min (approx. method)

Given an average flowrate of 2.25 l/s, and a maximum flowrate of 6.25 l/s, determine the slope and pipe diameter required for a minimum tractive force of 1 Pa and a maximum relative depth of $y/D = 0.7$. Manning's roughness = 0.013. See footnote¹¹

Step 1, solve for the slope

Assume y/D min is 0.2.

Switch to the “S-min program”. On the S min input screen, checkmark the “Manning n = const” and select the “S,D (τ min) given τ Q y/D ” solve option. Then press the OK tab.

Input screen for 7 S min program

```
Menu: 7 S min program
Manning n = const eq ☒
Manning n = f(D) eq ☐
Colebrook eq ☐
Solve: 4 S,D ( $\tau$  min) given  $\tau$  Q y/D
```

On the 2nd input screen for S,D (τ min) given τ Q y/D solve option, input the following and press the OK tab.

¹¹ The problem was shown on *Chart 3 Tractive force design chart example*, Christchurch City Council Infrastructure Design Standard, Part 6: Wastewater Drainage, Appendix 1, page 6-45, Sept. 2016.

Input screen for 05 S,D (τ min) given τ Q y/D

n:	0.013
τ :	1 Pa
Q:	2.25 l/s
D unit:	mm
y/D:	0.2
temp:	15° C

The print terminal indicates the approx. slope $S = 0.00388$.

Print Terminal

```

----- PipeCalc4c -----
07 S min program
05 S,D for  $\tau$  min given  $\tau$  Q y/D
Manning's Eq n=const
  > Manning n = 0.013
  > ave shear stress  $\tau = 1.0$  (N/m2)
  velocity V = 0.42373 (m/s)
  > flowrate Q = 2.25 (l/s)
  slope S = 0.00388 *
  slope ratio = 1 : 257.47
  diameter D = 217.91 mm * (a)
  > relative depth y/D = 0.2
  central angle  $\theta = 1.8546$  rad
  depth y = 43.582 mm
  > water temp = 15° C
  ---
  froude no. = 0.7753
  (equivalent ks = 1.5498 mm)
  area A = 0.00531 m2

```

```

hydraulic radius Rh = 0.02628 m
wetted perimeter P = 0.20207 m
top width T = 0.17433 m
Q full = 25.693 (l/s) y/D = 1 & 0.81963
Q peak = 27.638 (l/s) y/D = 0.93818
V full = 0.68893 (m/s) y/D = 1 & 0.5
V peak = 0.7854 (m/s) y/D = 0.8128
A full = 0.03729 m2
critical rel. depth Yc/D = 0.17566
critical depth Yc = 38.278 mm
kin viscosity VK = 1.1390E-6 Pa
density  $\rho = 999.10$  (kg/m3)
Notes
  • The calculation of  $\tau$  uses the approximate
    equation, where  $\sin(\theta) = S$ .
  (a) D is the calculated diameter. If Q min was
    used, then D calc is generally not used, as the
    pipe diameter is sized by Q max.

```

Step 2, solve for the diameter

Switch to the *Manning Flowrate Eq* $n=const$ equation. On the input screen enter n, Q max, Q min, S, y/D min, y/D max and other information shown, and press the OK tab.

Input screen for Manning Flowrate Eq

Menu: 1 Manning Flowrate Eq n=const	
n:	0.013
Q:	6.25 l/s
S:	0.00388
D:	0 mm
y/D:	0
temp 15° C	
Solve:	D $\uparrow$, y/D given n Q S

Separate Q low calcs for V, τ (optional)	
Q low ☒	2.25 % of Q ☐ 0
y/D low ☐	0
Diameter rounding parameters for D $\uparrow$	
y/D max for pipe sizing (0.1 to 1):	0.7
dia list:	Aus Composite (mm)
min dia row no.:	2

The print terminal indicates the diameter $D = 150$ mm and relative depth $y/D = 0.59223$. For the low flowrate, $V = 0.43989$ m/s, $\tau = 1.0577$ N/m² and $y/D = 0.33138$.

Print Terminal

<pre> ----- PipeCalc4c ----- 01 Manning Flowrate Eq n=const 06 Solve: D↑, y/D given n Q S ▸ Manning n = 0.013 ▸ flowrate Q = 6.25_(l/s) ▸ slope S = 0.00388 slope ratio = 1 : 257.47 nominal diameter D = 150_mm★ inside diameter ID = 150_mm (calculated diameter = 137.08_mm) ▸ y/D max for pipe sizing = 0.7 ▸ dia. list = Aus Composite (mm) ▸ minimum diameter row no. = 2 minimum diameter = 100_mm relative depth y/D = 0.59223★ depth y = 88.834_mm central angle θ = 3.5126_rad ▸ water temp = 15° C --- velocity V = 0.57344_(m/s) ave shear stress τ = 1.5743_Pa froude no. = 0.67348 </pre>	<pre> (equivalent ks = 1.6168_mm) area A = 0.0109_m^2 hydraulic radius Rh = 0.04137_m wetted perimeter P = 0.26345_m top width T = 0.14743_m Low flow calcs for Q low = 2.25_(l/s) V = 0.43989_(m/s) τ = 1.0577_(N/m^2) y/D = 0.33138 y = 49.707_mm Q full = 9.4912_(l/s) y/D = 1 & 0.81963 Q peak = 10.21_(l/s) y/D = 0.93818 V full = 0.53709_(m/s) y/D = 1 & 0.5 V peak = 0.6123_(m/s) y/D = 0.8128 critical rel. depth (y/D crit) = 0.48155 critical depth (y crit) = 72.232_mm kinematic viscosity νk = 1.1390E-6_Pa density ρ = 999.10E0_(kg/m^3) Notes • The calculation of τ uses the approximate equation, where sin(θ)=S. </pre>
---	--

8. Solve $S, y/D$ for τ min

In the previous problem, S and D for τ min were solved using an approximate method. Now that diameter is known, the exact S and y/D for τ min can be solved using the $S, y/D$ for τ min given $D \tau Q$ solve option in the S min program.

Run the $S, y/D$ for τ min given $D \tau Q$ solve option in the S min program. Enter $n = 0.013$, $D = 150$ mm, τ min = 1 Pa, Q min = 2.25 l/s, and temp = 15° C. Finally press the OK tab.

Input screen for 7 S min program

```

Menu: 7 S min program
  Manning n = const eq ☒
  Manning n = f(D) eq ☐
  Colebrook eq ☐
Solve: 6  S,y/D for τ min given D τ Q

```

On the 2nd input screen for S, D (τ min) given $\tau Q y/D$ solve option, input the following and press the OK tab.

Input screen for 06 $S, y/D$ for τ min given $D \tau Q$

```

n: 0.013
D: 150 mm
T min: 1 Pa
Q min: 2.25 l/s
temp: 15° C

```

The print terminal indicates the slope for τ min equals 0.00362 at a relative depth of 0.33762, which is a little different from the approx. method.

Print Terminal

```

----- PipeCalc4c -----
07 S min program
06 S,y/D for  $\tau$  min given D  $\tau$  Q
Manning's Eq n=const
  ▶ Manning n = 0.013
  ▶ ave shear stress  $\tau = 1_{(N/m^2)}$ 
    velocity V = 0.42877_(m/s)
  ▶ flowrate Q = 2.25_(l/s)
    slope S = 0.00362★
    slope ratio = 1 : 276.41
  ▶ diameter D = 150_mm
    relative depth y/D = 0.33762★
    central angle  $\theta = 2.4801_{rad}$ 
    depth y = 50.643_mm
  ▶ water temp = 15° C
  ---
    froude no. = 0.71193
    (equivalent ks = 1.56_mm)

```

```

area A = 0.00525_m^2
hydraulic radius Rh = 0.02821_m
wetted perimeter P = 0.18601_m
top width T = 0.14187_m
Q full = 9.1602_(l/s)  y/D = 1 & 0.81963
Q peak = 9.8537_(l/s)  y/D = 0.93818
V full = 0.51836_(m/s)  y/D = 1 & 0.5
V peak = 0.59095_(m/s)  y/D = 0.8128
A full = 0.01767_m^2
critical rel. depth Yc/D = 0.28329
critical depth Yc = 42.493_mm
kin viscosity VK = 1.1390E-6_Pa
density  $\rho = 999.10E0_{(kg/m^3)}$ 
Notes
  • The calculation of  $\tau$  uses the approximate
    equation, where  $\sin(\theta)=S$ .

```

9. Solving for S,D for V_{min}

There are several ways to solve for S,D $\uparrow$ for V_{min} . The first two methods require the use a pipe diameter list.

Size a storm pipe for $Q = 35$ l/s, where the available slope (ground slope) is 0.00124. y/D max = 0.75, and V min = 0.75 m/s. Use $ks = 0.6$ mm for the storm pipe.

Method 1. Slope for minimum velocity D-Q-S table

Run the *S min program*. On the input screen for the *S min program*, run the *S for V min D-Q-S table* program.¹²

Input screen for 7 S min program

```

Menu: 7 S min program
  Manning n = const eq ☐
  Manning n = f(D) eq ☐
  Colebrook eq ☒
Solve: 1 S for V min D-Q-S table

```

On the 2nd input screen for *S for V min D-Q-S table* program, input the following and press the OK tab.

¹² This procedure was based on “Table 7-7. Minimum pipe slope to ensure 0.9 m/s (3.0 ft/s) velocity in storm drains flowing full” in *Urban Drainage Design Manual*, Engineering Circular no. 22, Third Ed., Federal Highway Administration, Sept. 2009, p 7-29. The FHWA’s Table 7-7 was based on Manning’s equation. The above problem used the Colebrook equation.

Input screen for *V min slope D-Q-S table*

ks:	0.6	mm
V:	0.75	m/s
Q unit:	l/s	
dia list:	US Storm (soft metric rnd 10mm)	
y/D:	0.75	
temp:	15°	C

Q was given as 35 l/s. On the table below, find the smallest pipe that can handle 35 l/s. A 300 mm pipe can handle 42.65 l/s, and has a corresponding slope of 0.00183. (The D-Q-S table does not take into account the minimum slope for construction.)

Print Terminal

```

----- PipeCalc4c -----
07 S min program
01 S for V min D-Q-S table
Colebrook Eq
roughness ks = 0.6_mm
V = 0.75_(m/s)Q units = 1_(l/s)
dia. list = US Storm (soft metric rnd 10mm)
D units = 1_mm
y/D = 0.75
kin visc VK = water 15°C = 1.1390E-6_Pa
density ρ = water 15°C = 999.10E0_(kg/m^3)
D      Q min      S min
100    4.7389     0.00748
150    10.663     0.00443
200    18.956     0.00307
250    29.618     0.00231
300    42.65      0.00183
380    68.43      0.00136
460    100.27     0.00107
610    176.33     0.00076
760    273.72     0.00058

```

910	392.43	0.00046
1070	542.56	0.00038
1220	705.34	0.00032
1520	1094.9	0.00025
1680	1337.5	0.00022
1830	1587	0.0002
1980	1857.8	0.00018
2130	2150	0.00016
2290	2485.1	0.00015
2440	2821.3	0.00014
2590	3178.9	0.00013
2740	3557.8	0.00012
2900	3985.4	0.00011
3050	4408.4	0.00011
3200	4852.6	0.0001
3350	5318.2	0.0001
3510	5838.4	0.00009
3660	6348	0.00009

Method 2. Slope for min velocity, S min program's "D↑,S for V min given V Q y/D" solve option

Switch to the *S min program*. On the input screen for the *S min program*, run the *D↑,S for V min given V Q y/D* solve option.

Input screen for 7 S min program

Menu: 7 S min program	
Manning n = const eq	☐
Manning n = f(D) eq	☐
Colebrook eq	☒
Solve: 2 D↑,S for V min given V Q y/D	

On the 2nd input screen for *D↑,S for V min given V Q y/D* solve option, input the following and press the OK tab.

Input screen for $D \uparrow, S$ for V min given $V Q y/D$

ks: 0.6	mm
V: 0.75	m/s
Q: 35	l/s
Diameter rounding parameters for $D \uparrow$	
y/D max for pipe sizing (0.1 to 1): 0.75	
dia list: US Storm (soft metric rnd 10mm)	
min dia row no.: 2	temp: 15° C

The print terminal indicates slope $S = 0.00183$, and diameter $D = 300$ mm.

Print Terminal

```

----- PipeCalc4c -----
07 S min program
02 D↑,S for V_min given V Q y/D
Colebrook Eq
  ▸ roughness ks = 0.6_mm
  ▸ velocity V = 0.61547_(m/s)
  ▸ flowrate Q = 35_(l/s)
    slope S = 0.00183★
    slope ratio = 1 : 545.34
    nominal diameter D = 300_mm★
    inside diameter ID = 300_mm
    (calculated diameter = 271.77_mm)
  ▸ y/D max for pipe sizing = 0.75
  ▸ dia. list = US Storm (soft metric rnd 10mm)
  ▸ minimum diameter row no. = 2
    minimum diameter = 100_mm
    relative depth y/D = 0.75★
    central angle  $\theta = 4.1888\_rad$ 
    depth y = 225_mm
  ▸ water temp = 15° C
  ---
    shear stress  $\tau = 1.6261\_ (N/m^2)$ 

```

```

froude no. = 0.42009
(equivalent n = 0.01403)
area A = 0.05687_m^2
hydraulic radius Rh = 0.09051_m
wetted perimeter P = 0.62832_m
top width T = 0.25981_m
Q full = 46.978_(l/s)  y/D = 1 & 0.8239
Q peak = 50.364_(l/s)  y/D = 0.93977
V full = 0.6646_(m/s)  y/D = 1 & 0.5
V peak = 0.75417_(m/s)  y/D = 0.8128
A full = 0.07069_m^2
critical rel. depth Yc/D = 0.47901
critical depth Yc = 5.6576_in
kinematic viscosity vk = 1.1390E-6_Pa
density  $\rho = 999.10E0\_ (kg/m^3)$ 
Notes
  • The calculation of  $\tau$  uses the approximate
    equation, where  $\sin(\theta)=S$ .

```

Method 3. Slope for min velocity, solve by chain calculations using the velocity eq

Step 1. Solve for the diameter using $Q=VA$ eq

Switch to the $Q=VA$ Eq program. Input the known information shown as shown. Select solve for D, and press the OK tab.

Input screen for $Q=VA$ Eq program

Menu: 8 $Q=VA$ Eq	
Q: 35	l/s
V: 0.75	m/s
D: 0	mm
y/D: 0.75	
Solve: D	

The print terminal indicates the diameter $D = 271.77$ mm.

Print Terminal

```
----- PipeCalc4c -----
08 Q=VA Eq
03 Solve: D
  ▸ flowrate Q = 35_(l/s)
  ▸ velocity V = 0.75_(m/s)
    diameter D = 271.77_mm★
  ▸ relative depth y/D = 0.75
    depth Y = 203.82_mm
    central angle  $\theta$  = 4.1888_rad
    area A = 0.04667_m^2
```

```
area A (full) = 0.05801_m^2
wetted perimeter P = 0.56919_m
hydraulic radius Rh = 0.08199_m
top width T = 0.23536_m
```

Step 2. Solve for the slope using Colebrook velocity eq

Round the diameter upwards to 300 mm.

Rerun PipeCalc, and switch to the *Colebrook Velocity Eq* program

On the input screen, change the diameter to be 300. Input ks. Specify Q units. Solve for S. Press the OK tab.

Input screen for *Colebrook Velocity Eq*

```
Menu: 6 Colebrook Velocity Eq
ks: 0.6 mm
V: 0.75 m/s
S: 0
D: 300 mm
y/D: 0.75 temp 15° C
Solve: S Q units: l/s
```

The print terminal indicates the slope for V min is equal to 0.00183, which agrees with the Method 1 results.

Print Terminal

```
----- PipeCalc4c -----
06 Colebrook Velocity Eq
03 Solve: S
  ▸ roughness ks = 0.6_mm
  ▸ velocity V = 0.75_(m/s)
    slope S = 0.00183★
    slope ratio = 1 : 545.34
  ▸ diameter D = 300_mm
  ▸ relative depth y/D = 0.75
    depth y = 225_mm
    central angle  $\theta$  = 4.1888_rad
  ▸ water temp = 15° C
  ▸ Q units = 1_(l/s)
    Q = 42.65_(l/s)
  ---
ave shear stress  $\tau$  = 1.6261_(N/m^2)
froude1 no. = 0.51192
(equivalent n = 0.01151)
```

```
area A = 0.05687_m^2
hydraulic radius Rh = 0.09051_m
wetted perimeter P = 0.62832_m
top width T = 0.25981_m
Q full = 46.978_(l/s) y/D = 1 & 0.8239
Q peak = 50.364_(l/s) y/D = 0.93977
V full = 0.6646_(m/s) y/D = 1 & 0.5
V peak = 0.75417_(m/s) y/D = 0.8128
critical rel. depth (y/D crit) = 0.53124
critical depth (y crit) = 159.37_mm
kinematic viscosity  $\nu_k$  = 1.1390E-6_Pa
density  $\rho$  = 999.10E0_(kg/m^3)
Notes
  • The calculation of  $\tau$  uses the approximate
    equation, where  $\sin(\theta)=S$ .
```

Method 4. Slope for min velocity, solve by chain calculations using the flowrate eq

Step 1. Solve for the diameter using $Q=VA$ eq

Switch to the $Q=VA$ Eq program. Input the known information shown as shown. Select solve for D, and press the OK tab.

Input screen for $Q=VA$ Eq program

Menu:	8	$Q=VA$ Eq
Q:	35	l/s
V:	0.75	m/s
D:	0	mm
y/D:	0.75	
Solve:	D	

The print terminal indicates the diameter $D = 271.77$ mm.

Print Terminal

```
----- PipeCalc4c -----
08 Q=VA Eq
03 Solve: D
  ▷ flowrate Q = 35_(l/s)
  ▷ velocity V = 0.75_(m/s)
    diameter D = 271.77_mm*
  ▷ relative depth y/D = 0.75
    depth Y = 203.82_mm
    central angle  $\theta = 4.1888\_rad$ 
    area A = 0.04667_m^2
```

area A (full) = 0.05801_m^2 wetted perimeter P = 0.56919_m hydraulic radius Rh = 0.08199_m top width T = 0.23536_m

Step 2. Round the diameter and recalculate Q using $Q=VA$ eq

Round the calculated diameter ($D = 271.77$ mm) to 300 mm. The rounding of the diameter changes the parameters of the $Q=VA$ equation, so it will be necessary to rebalance the equation.

Run the $Q=VA$ Eq program. Using the 300 mm diameter, recalculate Q.

Input screen for $Q=VA$ Eq program

Menu:	8	$Q=VA$ Eq
Q:	0	l/s
V:	0.75	m/s
D:	300	mm
y/D:	0.75	
Solve:	Q	

The print terminal indicates flowrate $Q = 42.65$ _(l/s).

Print Terminal

```
----- PipeCalc4c -----
08 Q=VA Eq
01 Solve: Q
  flowrate Q = 42.65_(l/s)*
  ▸ velocity V = 0.75_(m/s)
  ▸ diameter D = 300_mm
  ▸ relative depth y/D = 0.75
    depth Y = 225_mm
    central angle  $\theta$  = 4.1888_rad
```

```
area A = 0.05687_m^2
area A (full) = 0.07069_m^2
wetted perimeter P = 0.62832_m
hydraulic radius Rh = 0.09051_m
top width T = 0.25981_m
```

Step 3. Solve for the slope using the Colebrook flowrate eq

Run the *Colebrook Flowrate Eq* program.

On the input screen, input $k_s = 0.6$ mm, and $\text{temp} = 15^\circ \text{C}$. Solve for S. Press the OK tab.

Input screen for Colebrook Flowrate Eq

```
Menu: 5 Colebrook Flowrate Eq
ks: 0.6 mm
Q: 42.65 l/s
S: 0
D: 300 mm
y/D: 0.75 temp 15° C
Solve: S
```

```
Separate Q low calcs for V,  $\tau$  (optional)
  Q low ☐ 0 % of Q ☐ 0
  y/D low ☐ 0
Diameter rounding parameters for D $\uparrow$ 
  y/D max for pipe sizing (0.1 to 1): 1
  dia list: US Storm (in)
  min dia row no.: 2
```

Print Terminal

```
----- PipeCalc4c -----
05 Colebrook Flowrate Eq
03 Solve: S
  ▸ roughness  $k_s = 0.6_{\text{mm}}$ 
  ▸ flowrate Q = 42.65_(l/s)
    slope S = 0.00183*
    slope ratio = 1 : 545.34
  ▸ diameter D = 300_mm
  ▸ relative depth y/D = 0.75
    depth y = 225_mm
    central angle  $\theta$  = 4.1888_rad
  ▸ water temp = 15° C
  ---
    velocity V = 0.75_(m/s)
    ave shear stress  $\tau = 1.6261_{\text{Pa}}$ 
    froude no. = 0.51192
    (equivalent n = 0.01151)
```

```
area A = 0.05687_m^2
hydraulic radius Rh = 0.09051_m
wetted perimeter P = 0.62832_m
top width T = 0.25981_m
Q full = 46.978_(l/s) y/D = 1 & 0.8239
Q peak = 50.364_(l/s) y/D = 0.93977
V full = 0.6646_(m/s) y/D = 1 & 0.5
V peak = 0.75417_(m/s) y/D = 0.8128
critical rel. depth (y/D crit) = 0.53124
critical depth (y crit) = 159.37_mm
kinematic viscosity  $\nu_k = 1.1390\text{E-}6_{\text{Pa}}$ 
density  $\rho = 999.10\text{E}0_{\text{(kg/m}^3\text{)}}$ 
Notes
  • The calculation of  $\tau$  uses the approximate
    equation, where  $\sin(\theta)=S$ .
```

10. Q Conversion example

Convert 4 MGD to an equivalent rate in cfs.

Switch to the *Q Conversions* program. On the input screen enter $Q_1 = 4$ MGD. Enter Q_3 units = ft^3/s . Set solve = Q_3 . Press the OK tab.

Input screen for *Q Conversions* program

```
Menu: 13 Q Conversions
Q1: 4 MGD
Q3: 0 ft3/s
Solve: Q3
```

The print terminal indicates the flowrate is equal to 4.0072 MGD.

Print Terminal

```
----- PipeCalc4c -----
13 Q Conversions
▷ flowrate Q1 = 4_(MgalUS/d)
  flowrate Q3 = 6.1889_(ft3/s)*
```

11. Revisions

Fixed a number format print error. Revised some of the S min programs. Added “% of Q” to the low flow inputs. Made minor changes to the program.

12. Program comments

Internal unit variables and unit handling

Unit variables are a list that contains the SI value part, SI unit part, user value part, user unit part, number that identifies if the variable is an input variable or solve variable, and input and output flags. The SI unit part is predefined in the variable declarations.

After data is inputted on the input screen, the program stores the user value part and user unit part into the unit variable. The program then calculates the SI value part. From this point on, all calculations in the program are done using the SI value part. After solving for the unknown variable, the SI values are converted back to the user’s units. The results are printed on the print terminal using the user value part multiplied by the unit part.

Diameter rounding adjustment

PipeCalc uses a diameter rounding adjustment of 0.6 mm. In the D↑ rounding procedure, 0.6 mm is subtracted from the calculated diameter, when rounding the diameter upwards. The HP-41 Pipe Slide Rule program used a diameter rounding adjustment of 0.003 in.