PipeCalc3, version L

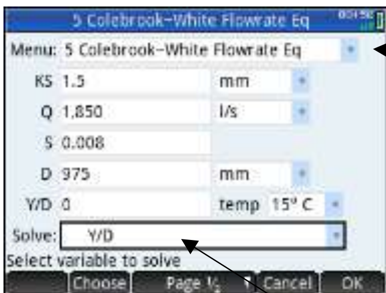
Pipe calculator for partial flow for the HP Prime Calculator

3/10/2023 by Eugene Shiomoto

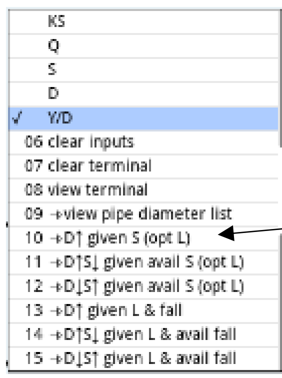
This pipe calculator program calculates the unknown variable for Manning n=const, Manning n=f(D), Colebrook-White, Continuity, Critical Flow, Shear Stress, and Raths-McCauley equations for a circular pipe flowing partially full. The program uses the calculator's unit functions, so the user must select the unit of the solve variable. The results are displayed on the calculator's print terminal. To change programs, select the new program from the program 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.

The title of the INPUT screen shows which program is currently running.

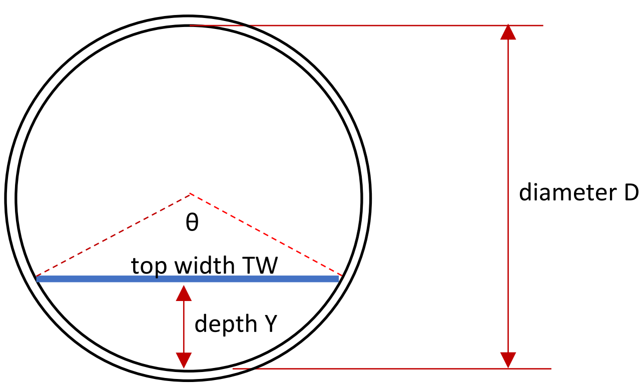
The Program Menu is used to change programs.



Select the variable to solve from the Solve Menu.



For the flowrate programs, the solve menu is also used to run the sub-programs to auto size pipes.



θ is the central angle and is sometimes referred to as PHI in the program.

Y/D = relative or proportional depth

Contents

1. Introduction and Disclaimer

The PipeCalc program is basically an equation solver for partial pipe flow with unit inputs. The user can solve an equation for any one variable, provided the other variables are known. The program can also perform some chain calculations.

Disclaimer

Use the PipeCalc program at your own risk.

The PipeCalc program and manual are supplied without representation or warranty of any kind. The author assumes no responsibility and shall have no liability of any kind arising from the use of this program and manual.

Usage

For education use.

PipeCalc was written as a replacement for the Field's Hydraulic Calculator and HP-41 Pipe Slide-Rule. PipeCalc is more of an educational program for engineers who used pipe slide rules in the past and are now learning to use the Colebrook-White and shear stress equations for partial flow. PipeCalc is not really suitable for design work.

Before using this program, the user should already know how to solve hydraulic problems by hand. This includes knowing how to derive the equations and formulas that are used. Otherwise, the user will just be feeding numbers into a black box.

For some time, the Hazen-Williams and Manning equations have been known to be fundamentally flawed, when compared to the Colebrook-White equation. This is partly due to the fact that the Hazen-Williams and Manning's equations do not properly adjust the frictional factor for changes in diameter. Countries, such as Germany, United Kingdom, European Union, Australia, and Hong Kong China have switched over, or begun to switch over to the Colebrook-White equation for partial pipe flow. The process to switch over to the Colebrook-White equation can take decades and is sometimes done in a piece meal fashion.

The Colebrook-White equation and Moody diagram are based on flow experiments with pipes, where the roughness height was relatively small. The Colebrook-White equation falls apart when the roughness height is large, because the large roughness's are outside of the roughness range used in the experiments. So, the Colebrook-White equation is generally not used for natural water channels, as the equivalent roughness can be large. In contrast, the Manning's equation can be used for both pipes and natural channels, but the Manning's equation still requires careful section of the n value of the natural channel. There is an experimental Colebrook-White like equation that has added a shape factor, but this and other similar equations are still in the experimental stage.

As previously noted, the Manning's equation does not accurately adjust the friction factor with changes in the pipe diameter. A work around is to manually adjust the n value with the diameter. This program includes a Manning n=f(D) program that varies n with the diameter to compensate for the n versus diameter inadequacy of the Manning's equation. The program uses the three NC classifications that are listed in the 2007 ASCE Manual 60.

The Manning and possibly the Colebrook-White equations do not work well with corrugated metal pipe, particularly helical CMP. A work around for the Manning's equation is to vary the n value with the diameter or use just use the largest n value for all diameters. This program includes a Manning n=f(D) program that varies the n value with the diameter for two helical corrugated steel pipes.

The Manning equations in PipeCalc do not adjust the roughness value for changes in depth by using the 1947 depth versus n-value chart by Camp. According to the 2007 ASCE Manual 60, the Manning n value does not significantly increase until the conduit is less than 10% full and noted that the chart of depth versus n value by Camp has errors. The ASCE manual suggests that it is not practical to adjust the n value for changes in depth. (I don't know if the Colebrook-White equation has the same problem.) In any event, the Manning n=f(D) program includes a work around for one of the helical corrugated steel pipes for partial flow, where the n value is increased 11 percent over the corresponding full flow value, regardless of the actual partial flow depth, in accordance with the 2012 FHWA Hydraulic Design of Highway Culverts.

In addition to the shift to the Colebrook-White equation, roughness tables in some publications have changed, where the tables include roughness values for extreme conditions, such as calcification or formation of a biofilm, or have variable values based on velocity. Some of these changes appear to be driven by lawsuits, where the roughness value was significantly underestimated, causing the pipe to be undersized.

2. Installation

Calculator Software Version

This program was written on a G1, hardware A, physical calculator running software version 2.1.14603 (2021 12 02), CAS version 1.5.0, and operating system V0.050.640. The virtual calculator and connectivity kit used Build 2.1.14592 (2021 6 9). Some editing was done on Notepad++ v7.3.1.

The CASE statements in the program uses the newer format, where the case IF statements do not end with a ";". Also, the subroutines and functions used in the program are not declared. These programming formats may prevent this program from running on calculators using earlier software versions.

This program was never tested on a G2 calculator.

Installing the program on the physical G1 calculator (hardware A)

It is suggested that older versions of PipeCalc be deleted from the calculator.

The following applies to the G1 hardware A physical calculator running software version 2.1.14603 (2021 12 02) and connectivity kit running Build 2.1.14592 (2021 6 9).

When connecting a G1, hardware A, calculator to the HP connectivity kit, the calculator icon will appear in the calculator panel as "HP Prime". For software 2021 12 02, one generally cannot expand the HP Prime folder. Doing so will crash the physical calculator, causing the physical calculator to reset. When the physical calculator resets, the HP splash screen is displayed for about 1 second. This problem only applies to the physical calculator and not to the virtual calculator.

So, when connecting the G1 hardware A calculator to the HP connectivity kit, do not open the "HP Prime" folder.

To load the PipeCalc program onto the physical calculator, simply drag and drop the *PipeCalc3.hpprgm* file onto the "HP Prime" folder shown on the connectivity kit. Just don't open the folder. Wait for the entire file to load and be processed by the calculator, before disconnecting the calculator from the connectivity kit.

Set the program to "read only"

The PipeCalc program is too large for the calculator's program editor and touchscreen, so it is suggested the program be set to "read only".

After the program has been installed on the calculator, open the program catalog by pressing Shift Program. On the program catalog, select the PipeCalc program and press the Edit tab. The program's HP BASIC code will be displayed. It may take two tries to display the program code. Tap the "More" tab, and enable or checkmark "Read Only". Press Esc key to exit the program editor. Press the Esc key a second time to exit the program catalog.

This was done, because using the program editor and touchscreen will eventually crash the hardware A calculator. In "Read Only" mode, you cannot edit the program and crash the calculator. Further, the kinetic scrolling is disabled, page down only advances the program by one line, and the Go To line function will not work.

I don't know if the same problem exists with a G2 calculator.

3. Instructions

Run the program

Use the toolbox key to run the program for the first time. Press the toolbox key, select the User tab, select PipeCalc3 program, and finally select the PipeCalc3 subprogram. This enters “PipeCalc3” into the entry line. Press the Enter key to launch the program.

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.

When PipeCalc is run a second time, the program will run the last program that was used and will display the previous input entries and unit selections.

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 box and then press the OK tab located in the lower right corner of the screen.

If the title of the INPUT screen is the same as the program shown in the Menu box, pressing the OK tab will run the program. If the title of the INPUT screen is different from the program in the Menu box, pressing the OK tab will switch to the program in the Menu box. It may take a while to get use to this menu style.

Calculator Entry Format

PipeCalc can be run in textbook or algebraic entry mode. However, PipeCalc should not be run in RPN entry mode, as one cannot rerun the program by pressing the Enter key.

When using Textbook entry mode, as one types in the expression, the expression is not correctly displayed on the edit line of the INPUT screen. However, the calculator will accept the expression. When typing in "1/250" for the slope, the edit line displays 1, then ▣, and then 250. When the Enter key is pressed, 0.004 appears in the input box for the slope.

Display Number Format and Set No. of Digits

The number format used in PipeCalc is floating with 4 digits. The number of digits can be changed using program 16, Set no. of digits. Just enter a new number of digits (4 to 10 digits) and press the OK tab. A message box will confirm that the number of digits has been changed. On the message box, press the OK tab to continue with the program.

The floating number format will hide cumulative errors. A calculated diameter of 36.000000416 will appear as 36 on the input screen and print terminal. The floating format is used to reduce the number of digits cluttering the input screen and print terminal.

Home Number Format and "See Symbolic Setup" option

If Home number format is set to "See Symbolic Setup", and you want to get out of "See Symbolic Setup" mode, go to the Home screen, and in the entry line, type "AFormat=1", then press the OK tab. Then press the Home settings and change the number format to the desired format.

In software version 2.1.14603 (2021 12 02) or possibly earlier, the AFormat "See Symbolic Setup" option appears to have been deleted from the CAS settings. As a result, PipeCalc3 version j was revised to not use or set AFormat. The AFormat variable can also be accessed by the Vars key, App tab, current App name (such as the Function App), Modes, and finally, select AFormat. This just types "AFormat" into the entry line.

When running the program, the input and print terminal will use the current Home number setting, with the exception that the print terminal will not print the thousands separator. When running the program in CAS, the CAS number format settings are ignored. (It is recommended that the program be run from the Home screen.)

PipeCalc will temporarily change the Angle, Number, and Digits Formats.

When the PipeCalc program is run, the program will change the AAngle setting to radians, HFormat setting to floating format, and HDigits to 4 digits. When the PipeCalc program ends, the program will restore the original settings. When running the program, if the program crashes before reaching the end of the program, the angle, number, and digit format settings will not be restored to the original settings. Should this happen, the user must manually restore the format settings.

Home and CAS

PipeCalc3 version j was revised so that the program can be run in both Home and CAS on software version 2.1.14603 (2021 12 02). However, it is suggested that the program be only run on the Home screen.

Solve Menu

The top part of the Solve menu list the variables to solve. For example, to solve for Q using the Manning's flowrate equation, enter the unknown values and units, including the flowrate unit. In the Solve menu, select Q, and press the OK tab in the lower right corner of the screen. The program will solve for Q, and display the answer on the print terminal.

The lower part of the Solve menu list used to clear the input screen, clear the print terminal, view the print terminal, or run sub-programs.

Clear Input. To clear inputs, select "clear input" from the Solve menu and press the "OK" tab. Clearing the inputs does not change the unit selections.

Clear terminal. To clear the print terminal, select "clear terminal" from the solve menu, and press the OK tab. After pressing the OK tab, a message box will confirm that the terminal was cleared. Press the OK tab to continue with the program.

When viewing the print terminal, pressing the correction or backspace key will clear the print terminal.

View terminal. This function allows one to view the terminal on the virtual calculator. After selecting "view terminal" from the Solve menu and pressing the OK tab, the program will end and display the print terminal.

On the physical calculator, one can also view the print terminal by pressing both the On and T keys.

→sub-programs. A few of the programs have sub-programs located at the end of the Solve menu list. To run a sub-program, select the sub-program from the Solve menu and press the OK tab. PipeCalc will go to a new input screen for the sub-program. Enter all of the requested values and units and press the OK tab. The print terminal will display the results. The → means that the program goes to a new input screen. The sub-input screen does not have a Menu or Solve box. To go back to the main input screen, press the Cancel tab or Esc key.

Access the program's input and output

Some of the program's input and output is saved to exported variables that can be access by the user using the Vars key, User tab, program name, and variable name. For the variable name, the "in" prefix stands for input, and the "out" prefix stands for output. "inYD1" is the relative depth Y/D for the lower solution. "outYD2" is the relative depth Y/D for the upper solution, if the second solution exists. If the second solution does not exist, outYD2 is supposed to be zero. The values contained in the input and output variables are in user units that was previously selected by the user. When running a specific program, unused input and output variables are generally cleared, so you cannot use values from two prior calculations ago.

Exit the Program

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

If you are on a sub-program INPUT screen, you have to press Esc or Cancel once to return to the main input screen. Then, press Esc or Cancel a second time to exit the program.

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

Program locks up and won't quit

You should always be able to quit PipeCalc by pressing the Esc key or Cancel tab. In the event the program locks up and you cannot quit the program, press and hold the Vars key, then press the On key, and then release all keys. This will quit the program and return you to the Home or CAS screen, *without restarting the calculator or clearing the program memory*. This procedure is undocumented and appears to be specific to software version 2.1.14603 (2021 12 02). In older software versions, you would just press the On key.

Error Messages

The program will check for some basic input errors. When an error is detected, such as entering 0 for a known variable, the program will either (1) display an error message in a message box on the Home screen, or (2) print the error message on the print terminal. If a message box is displayed, pressing the OK tab will display the last input screen with the input values containing the error. The user simply corrects the error and continues with the program.

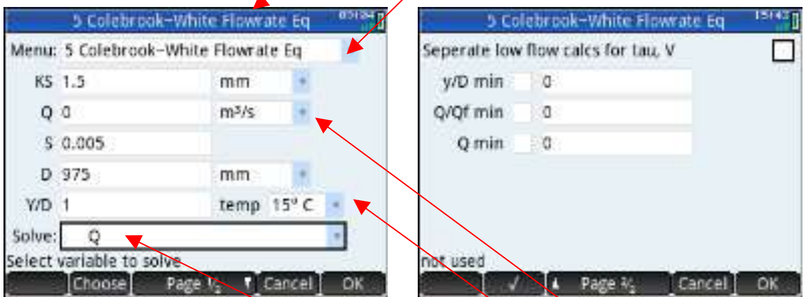
3.1. Solve for Q using the Colebrook-White flowrate equation

Determine the flowrate and velocity of a 975 mm pipe flowing full with a slope of 0.005, k_s = 1.5 mm and water at 15°C.

(answer from Wallingford and Barr's Table A30, 2004, Q = 1.5572 m^3/s, V = 2.086 m/s.)

The input screen title shows which program is running.

Use the Menu box to select another program to run. Then, press the OK tab to switch programs.



Select the units of the unknow variable.

Select the water temperature for the kinematic viscosity.

Select which variable to solve.

After everything has been inputted, press the OK tab to see the results on the print terminal.

The output is displayed on the print terminal.

----
05 Colebrook−White Flowrate Eq
02 Solve: Q
▹ roughness KS = 1.5_mm
flowrate Q = 1.5571_(m^3/s)✱
Q/Qf = 1.0
▹ slope S = 0.005
slope ratio = 1 : 200
▹ diameter D = 975_mm
▹ water temp = 15° C
▹ relative depth Y/D = 1
depth Y = 975_mm
central angle θ = 6.2832_rad
---
velocity V = 2.0855_(m/s)
V/Vf = 1
V head = 0.22175_m
pressure head = 0.975_m
shear stress τ = 11.941_Pa
shear stress τ = 0.2494_(lbf/ft²)
froude1 no. = not applic.
(equivalent N = 0.01323)
area A = 0.74662_m^2
hydraulic radius HR = 0.24375_m
wetted perimeter WP = 3.0631_m
top width TW = not applic.
Q full = 1.5571_(m^3/s) y/D = 1 & 0.82662
Q peak = 1.6657_(m^3/s) y/D = 0.94071
V full = 2.0855_(m/s) y/D = 1 & 0.5
V full head = 0.22175_m
V peak = 2.3597_(m/s) y/D = 0.8128
A full = 0.74662_m^2
critical rel. depth Yc/D = 0.74314
critical depth Yc = 724.56_mm
Reynolds no. (KS1) = 1.7852ᴇ6
kin visc VK = water 15°C = 1.1390ᴇ-6_Pa
density ρ = water 15°C = 999.10ᴇ0_(kg/m^3)
Notes
• The calculation of τ uses the approximate equation, where sin(θ)=S.

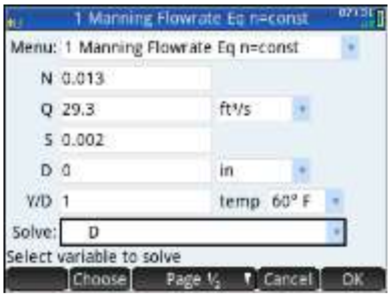
3.2. Example to find the diameter of a storm pipe and manually round the diameter up using the Manning's and Colebrook-White equations

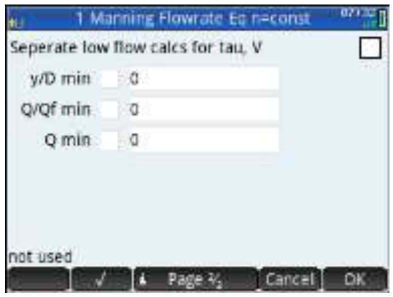
Given a flow rate of 29.3 cfs and a ground slope of 0.002, size a concrete pipe to handle the flow using (a) Manning's constant n equation for full flow with n = 0.013, (b) Colebrook-White equation for y/D max = 0.75 and KS = 0.6 mm, and (c) for the Colebrook-White problem, what is the pipe capacity if the roughness degrades from 0.6 mm to 1.5 mm over the life of the pipe?

a. Solve D using Manning eq, y/D = 1, n = 0.013

Run the PipeCalc program. The top of the input screen will show the current program that is running. If necessary, switch to the Manning Flowrate (n=const) program by selecting "Manning Flowrate Eq n=const" in the Menu box and press the OK tab.

On the input screen for Manning Flowrate Eq n=const, input the known values and units. The diameter is the variable to be solved. Select the diameter unit to be inch. Select "Solve" = D. Press the OK tab. The program will display D = 35.76_in on the print terminal.



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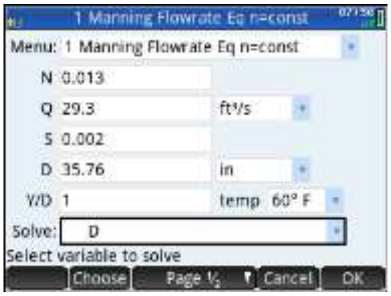
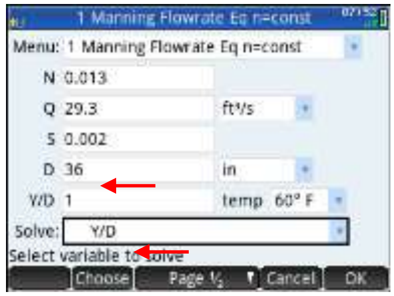
------------------------------------
01 Manning Flowrate Eq n=const
04 Solve: D
 ▹ Manning N = 0.013
 ▹ flowrate Q = 29.3_(ft^3/s)
   Q/Qf = 1.0
 ▹ slope S = 0.002
   slope ratio = 1 : 500
   diameter D = 35.76_in*
 ▹ water temp = 60° F
 ▹ relative depth Y/D = 1
   depth Y = 35.76_in
   central angle θ = 6.2832_rad
   ---
   velocity V = 4.2009_(ft/s)
   V/Vf = 1.0
   V head = 0.27425_ft
   pressure head = 2.98_ft
   shear stress τ = 0.09292_(lbf/ft²)
   shear stress τ = 4.4491_Pa
   froude1 no. = not applic.
   (equivalent KS = 1.3108_mm)
   area A = 6.9747_ft^2
   hydraulic radius HR = 0.745_ft
   wetted perimeter WP = 9.362_ft
   top width TW = not applic.
Q full = 29.3_(ft^3/s)   y/D = 1 & 0.81963
Q peak = 31.518_(ft^3/s)   y/D = 0.93818
V full = 4.2009_(ft/s)   y/D = 1 & 0.5
V full head = 0.27425_ft
V peak = 4.7891_(ft/s)   y/D = 0.8128
A full = 6.9747_ft^2
critical rel. depth Yc/D = 0.58939
critical depth Yc = 21.077_in
Reynolds no. (KS1) = 1.0287E6
kin visc VK = water 60°F = 12.170E-6_(ft^2/s)
density ρ = water 60°F = 1.9383E0_(slug/ft^3)
Notes
• The calculation of τ uses the approximate
equation, where sin(θ)=S.
```

The above terminal shows the calculated diameter to be 35.76_in. Manually round the diameter upward to 36 in. Rerun PipeCalc and solve for Y/D using the rounded diameter of 36 in. This is done by pressing the Esc key to exit the terminal. Press the Enter key to run the PipeCalc program again. The input screen for the Colebrook-White flowrate program is shown with the previous inputs and calculated diameter of 35.76 in. On the input screen, change the diameter to 36. Change the solve variable to Y/D. Press the OK tab.

Input screen when PipeCalc is run again



Input screen with changes



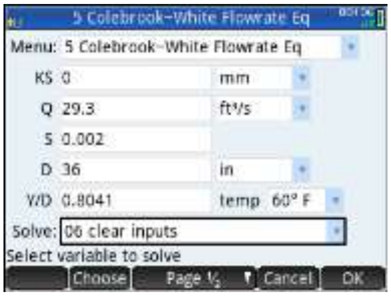
----
01 Manning Flowrate Eq n=const
05 Solve: Y/D
▹ Manning N = 0.013
▹ flowrate Q = 29.3_(ft^3/s)
Q/Qf = 0.98234
▹ slope S = 0.002
slope ratio = 1 : 500
▹ diameter D = 36_in
▹ water temp = 60° F
relative depth Y/D = 0.8041 ✶
depth Y = 28.948_in
central angle θ = 4.4492_rad
---
velocity V = 4.8099_(ft/s)
V/Vf = 1.1399
V head = 0.35954_ft
pressure head = 2.4123_ft
shear stress τ = 0.11385_(lbf/ft²)
shear stress τ = 5.4509_Pa
froude1 no. = 0.53019
(equivalent KS = 1.2292_mm)
area A = 6.0916_ft^2
hydraulic radius HR = 0.91276_ft
wetted perimeter WP = 6.6737_ft
top width TW = 2.3814_ft
Q full = 29.827_(ft^3/s) y/D = 1 & 0.81963
Q peak = 32.085_(ft^3/s) y/D = 0.93818
V full = 4.2196_(ft/s) y/D = 1 & 0.5
V full head = 0.2767_ft
V peak = 4.8105_(ft/s) y/D = 0.8128
A full = 7.0686_ft^2
critical rel. depth Yc/D = 0.58427
critical depth Yc = 21.034_in
Reynolds no. (KS1) = 1.4430E6
kin visc VK = water 60°F = 12.170E-6_(ft^2/s)
density ρ = water 60°F = 1.9383E0_(slug/ft^3)
Notes
• The calculation of τ uses the approximate equation, where sin(θ)=S.

Solve D using Colebrook-White eq, y/D max = 0.75, KS = 0.6 mm

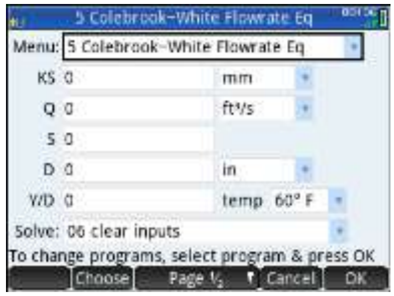
Rerun the program by pressing the Esc key to exit the print terminal, and then press the Enter key to run the PipeCalc program. The input screen for the Manning Flowrate is displayed with the previous inputs. Switch to the Colebrook-White program by selecting "Colebrook-White Flowrate Eq" in the Menu box and then tap the OK tab in the lower right corner of the screen. The previous inputs from the Manning Eq are displayed, except that KS value displays a value of 0.

At this point you can just make the following changes: KS = 0.6 mm, Y/D = 0.75 and Solve = D, similar to what was done for example (a). However, for this example, the previous inputs will be cleared. To clear the previous input values, in the Solve box, select "clear inputs" and press the OK tab. Clear inputs will not change the unit selections.

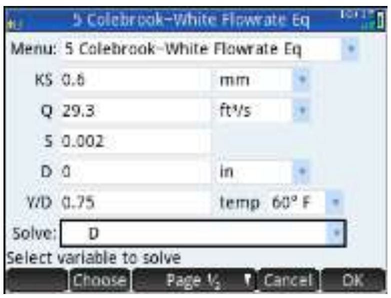
Input screen before clearing inputs

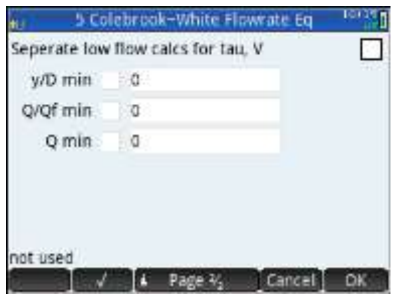


Input screen after clearing inputs



On the input screen for Colebrook-White Flowrate Eq, input the known values and units as shown below. The diameter is the variable to be solved. Select the diameter unit to be inch. Select "Solve" = D. Press the OK tab. The program will display D = 35.912_in on the print terminal.





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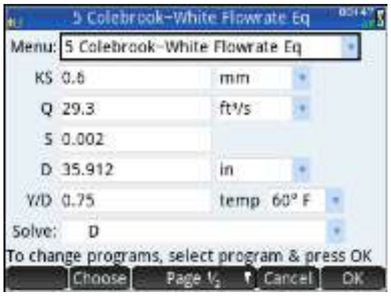
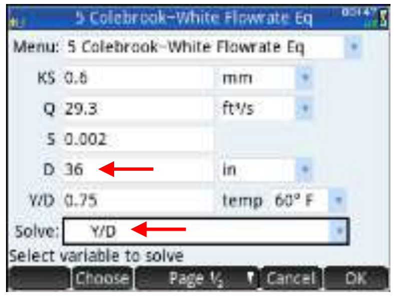
05 Colebrook−White Flowrate Eq
04 Solve: D
▹ roughness KS = 0.6_mm
▹ flowrate Q = 29.3_(ft^3/s)
Q/Qf = 0.90398
▹ slope S = 0.002
slope ratio = 1 : 500
diameter D = 35.912_in∗
▹ water temp = 60° F
▹ relative depth Y/D = 0.75
depth Y = 26.934_in
central angle θ = 4.1888_rad
−−−
velocity V = 5.1777_(ft/s)
V/Vf = 1.1237
V head = 0.41662_ft
pressure head = 2.2445_ft
shear stress τ = 0.11261_(lbf/ft²)
shear stress τ = 5.3917_Pa
froude1 no. = 0.61775
(equivalent N = 0.01199)
area A = 5.6588_ft^2
hydraulic radius HR = 0.90284_ft
wetted perimeter WP = 6.2678_ft
top width TW = 2.5917_ft
Q full = 32.412_(ft^3/s) y/D = 1 & 0.82816
Q peak = 34.631_(ft^3/s) y/D = 0.94125
V full = 4.6079_(ft/s) y/D = 1 & 0.5
V full head = 0.32997_ft
V peak = 5.2055_(ft/s) y/D = 0.8128
A full = 7.034_ft^2
critical rel. depth Yc/D = 0.58614
critical depth Yc = 21.049_in
Reynolds no. (KS1) = 1.5365E6
kin visc VK = water 60°F = 12.170E−6_(ft^2/s)
density ρ = water 60°F = 1.9383E0_(slug/ft^3)
Notes
• The calculation of τ uses the approximate equation, where sin(θ)=S.

The terminal shows the calculated diameter to be 35.912_in. Manually round the diameter upward to 36 in. Rerun PipeCalc and solve for Y/D using the rounded diameter of 36 in. This is done by pressing the Esc key to exit the terminal. Press the Enter key to run the PipeCalc program again. The input screen for the Colebrook-White flowrate program is shown with the previous inputs and calculated diameter of 35.912 in. On the input screen, change the diameter to 36. Change the solve variable to Y/D. Press the OK tab.

Input screen before making changes



Input screen after making changes



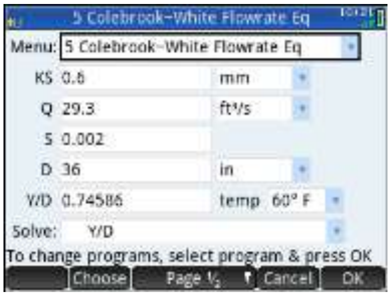

```
-----------------------------------
05 Colebrook−White Flowrate Eq
05 Solve: Y/D
  ▹ roughness KS = 0.6_mm
  ▹ flowrate Q = 29.3_(ft^3/s)
    Q/Qf = 0.89818
  ▹ slope S = 0.002
    slope ratio = 1 : 500
  ▹ diameter D = 36_in
  ▹ water temp = 60° F
    relative depth Y/D = 0.74586✱
    depth Y = 26.851_in
    central angle θ = 4.1697_rad
    ---
    velocity V = 5.1819_(ft/s)
    V/Vf = 1.1228
    V head = 0.4173_ft
    pressure head = 2.2376_ft
    shear stress τ = 0.11276_(lbf/ft²)
    shear stress τ = 5.3988_Pa
    froude1 no. = 0.62095
    (equivalent N = 0.01199)
    area A = 5.6543_ft^2
    hydraulic radius HR = 0.90403_ft
    wetted perimeter WP = 6.2545_ft
    top width TW = 2.6123_ft
Q full = 32.621_(ft^3/s)    y/D = 1 & 0.82817
Q peak = 34.855_(ft^3/s)    y/D = 0.94125
V full = 4.615_(ft/s)    y/D = 1 & 0.5
V full head = 0.33098_ft
V peak = 5.2134_(ft/s)    y/D = 0.8128
A full = 7.0686_ft^2
critical rel. depth Yc/D = 0.58427
critical depth Yc = 21.034_in
Reynolds no. (KS1) = 1.5397E6
kin visc VK = water 60°F = 12.170E-6_(ft^2/s)
density ρ = water 60°F = 1.9383E0_(slug/ft^3)
Notes
● The calculation of τ uses the approximate
equation, where sin(θ)=S.
```

c. For the Colebrook-White problem, what is the pipe capacity if the roughness degrades from 0.6 mm to 1.5 mm over the life of the pipe?

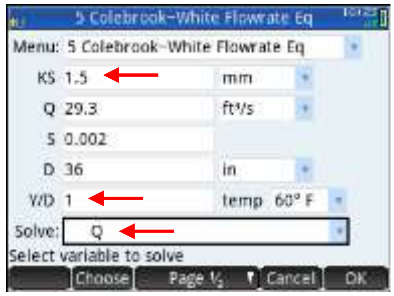
For this problem, we use Pipe Calc to solve for Q full for KS = 1.5 mm. Rerun the program by pressing the Esc key to exit the print terminal, and then press the Enter key to run the PipeCalc program. The Colebrook-White

Flowrate input screen is displayed with the previous inputs.   Change KS to 0.15 mm, Y/D to 1, and Solve to "Q". Then press the OK tab.

Input screen when PipeCalc is rerun



Input screen after making changes



----
05 Colebrook–White Flowrate Eq
02 Solve: Q
▹ roughness KS = 1.5_mm
flowrate Q = 29.325_(ft^3/s)∗
Q/Qf = 1.0
▹ slope S = 0.002
slope ratio = 1 : 500
▹ diameter D = 36_in
▹ water temp = 60° F
▹ relative depth Y/D = 1
depth Y = 36_in
central angle θ = 6.2832_rad
---
velocity V = 4.1486_(ft/s)
V/Vf = 1.0
V head = 0.26747_ft
pressure head = 3_ft
shear stress τ = 0.09354_(lbf/ft^2)
shear stress τ = 4.4789_Pa
froude1 no. = not applic.
(equivalent N = 0.01322)
area A = 7.0686_ft^2
hydraulic radius HR = 0.75_ft
wetted perimeter WP = 9.4248_ft
top width TW = not applic.
Q full = 29.325_(ft^3/s)   y/D = 1 & 0.82623
Q peak = 31.38_(ft^3/s)   y/D = 0.94057
V full = 4.1486_(ft/s)   y/D = 1 & 0.5
V full head = 0.26747_ft
V peak = 4.6961_(ft/s)   y/D = 0.8128
A full = 7.0686_ft^2
critical rel. depth Yc/D = 0.58453
critical depth Yc = 21.043_in
Reynolds no. (KS1) = 1.0227E6
kin visc VK = water 60°F = 12.170E-6_(ft^2/s)
density ρ = water 60°F = 1.9383E0_(slug/ft^3)
Notes
• The calculation of τ uses the approximate equation, where sin(θ)=S.

Comment

In the U.S., storm drain pipes are often sized with the Manning equation using y/D = 1 and n = 0.013, where manhole bends and junctions require an elevation drop equal to the minor loss.

In the U.K., storm drain pipes are often sized with the Colebrook-White equation with a ks value of 0.6 mm and y/D max of 0.75. Wallingford and Barr Table of recommended roughness values for precast concrete pipe are: good condition = 0.06 mm, normal condition = 0.15 mm, and poor condition = 0.6 mm. For this specific example, the equivalent n values of the Wallingford and Barr roughness values are: good condition n = 0.00995, normal condition n = 0.01055, and poor condition n = 0.01199. For ks = 1.5 mm used in problem c, the equivalent

Manning n value is 0.01322. So, the U.K. uses a roughness value for poor condition pipes. For this particular example, the poor condition roughness has an equivalent n value of 0.01199. This equivalent n value is 7.7% lower than the 0.013 n value used in the U.S.

Comparison of the pipe sizing results for Q = 29.3 cfs and S = 0.002

Method	Equiv. N Value	Calc D (in)	D (in)
Manning (const n), y/D = 1, n = 0.013	0.013	35.76 ←	36
Colebrook-White, y/D max = 0.75, ks = 0.6 mm	0.012	35.91 ←	36

Although the equivalent n value for the Colebrook-White method is 7.7% lower than the n value used for the Manning eq method, the two methods gave similar results when solving for the diameter, as noted by the similar calculated diameters for each method. The calculated diameters are similar, because the Colebrook-White method used y/D max = 0.75 to size the pipe, while the Manning's method used y/D max = 1. For the Colebrook-White method, if Y/D max was equal to 1, the calculated diameter would be 34.556 in.

Regarding problem (c), if the pipe's ks roughness was to degrade from 0.6 mm to 1.5 mm over the life of the pipe (which is the approximate equivalent n value of 0.013 used in the U.S.), the pipe would still be able to handle the design flow of 29.3 cfs by utilizing the space in the pipe that is above the 0.75 relative depth.

I don't know why the U.K. decided to use y/D max = 0.75 for storm drainage designs, but I would guess that it may have been done to make the designs calculated by the Colebrook-White equation more similar to designs calculated by the Manning equation or to retain the conservative safety factor of using n = 0.013 in the Manning equation. The former reason might have been necessary when making changes to old storm drainage systems that were design with the Manning's equation, so that the new designs using the Colebrook-White equation would not be significantly out of whack with the old designs. The later reason might have been necessary, because the U.K. may have encountered old storm drain concrete pipes that have a ks value of 1.5 mm, and wanted the Colebrook-White design method to be able to handle pipes with a roughness that has degraded to 1.5 mm. But all of this is just speculation.

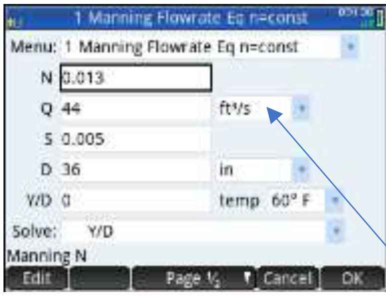
Pipe sizing results for Colebrook-White method for Q = 29.3 cfs, S = 0.002, and ks = 0.6 mm

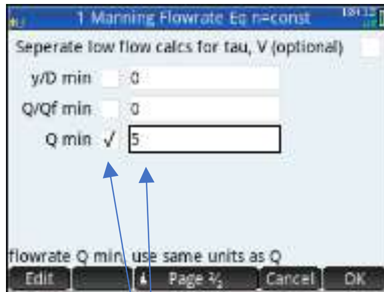
y/D (sizing)	Calc D (in)
1.00	34.56
0.94	33.69
0.90	33.83
0.85	34.28
0.80	34.98
0.75	35.91 ←
0.70	37.09
0.65	38.54
0.60	40.29

3.3. Separate low flow calcs for the flowrate programs

PipeCalc has three flowrate programs – Manning n=const, Manning n=f(D), and Colebrook-White programs. Each of these programs have optional inputs for low flow calculations, located on the second page of the input screen. The user can input y/D min, Q/Qf min, or Q min. To use one of these inputs, the adjacent checkbox must be checked. The Q min input does not have a unit selection box. So, the minimum flowrate must be in the same units as used for the flowrate Q on page one of the input screen.

When using one of the low flow inputs, PipeCalc will perform a separate calculation that calculates the velocity shear stress, and relative depth for the low flow.





This checkbox is not used. (It just a way to print a text header on the input screen.)

Q min input equal to 5 cfs.

The adjacent checkbox needs to be checked.

Q min uses the same units as Q on page one of the input screen.

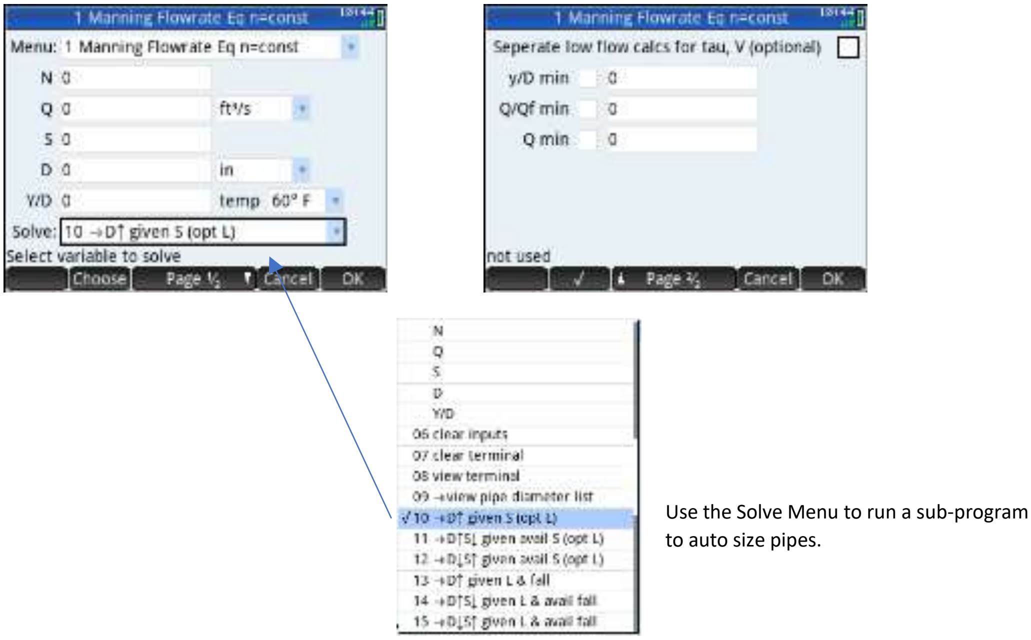
----
01 Manning Flowrate Eq n=const
05 Solve: Y/D
▹ Manning N = 0.013
▹ flowrate Q = 44_(ft^3/s)
Q/Qf = 0.93299
▹ slope S = 0.005
slope ratio = 1 : 200
▹ diameter D = 36_in
▹ water temp = 60° F
relative depth Y/D = 0.76525✶
depth Y = 27.549_in
central angle θ = 4.26_rad
---
velocity V = 7.5806_(ft/s)
V/Vf = 1.1362
V head = 0.89304_ft
pressure head = 2.2957_ft
shear stress τ = 0.28324_(lbf/ft^2)
shear stress τ = 13.561_Pa
froude1 no. = 0.88462
(equivalent KS = 1.2498_mm)
area A = 5.8043_ft^2
hydraulic radius HR = 0.90834_ft
wetted perimeter WP = 6.39_ft
top width TW = 2.5431_ft
Q full = 47.16_(ft^3/s) y/D = 1 & 0.81963
Q peak = 50.731_(ft^3/s) y/D = 0.93818
V full = 6.6718_(ft/s) y/D = 1 & 0.5
V full head = 0.69176_ft
V peak = 7.6061_(ft/s) y/D = 0.8128
A full = 7.0686_ft^2
Low flow calcs for Q min = 5_(ft^3/s)
V = 4.3397_(ft/s)
shear stress τ = 0.12268_(lbf/ft^2)
shear stress τ = 5.874_Pa
Y/D = 0.21988
Q/Qf = 0.10602
critical rel. depth Yc/D = 0.72041
critical depth Yc = 25.935_in
Reynolds no. (KS1) = 2.2632E6
kin visc VK = water 60°F = 12.170E-6_(ft^2/s)
density ρ = water 60°F = 1.9383E0_(slug/ft^3)
Notes
• The calculation of τ uses the approximate equation, where sin(θ)=S.

Low flow calculations for Q = 5 cfs

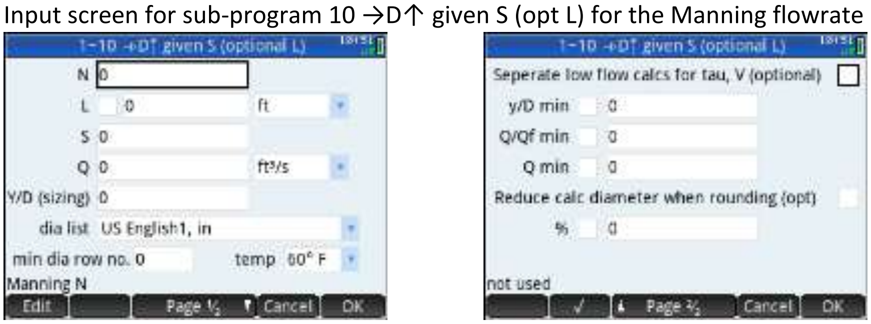
3.4. Auto Pipe Sizing sub-programs for the flowrate programs

PipeCalc has three flowrate programs – Manning n=const, Manning n=f(D), and Colebrook-White programs. Each of these programs have auto pipe sizing sub-programs that are located near the bottom of the Solve Menu. To switch to a sub-program, select the sub-program from the Solve menu and press the OK tab. The program will display the sub-program input screen. On the sub-program input screen input the requested inputs and then press the OK tab to run the program. The results of the program are displayed on the print terminal.

Input screen for the Manning Flowrate Eq n=const



Input screen for sub-program 10 →D↑ given S (opt L) for the Manning flowrate n=const program



Solve 10 →D↑ given S (opt L)

The "Solve 10 →D↑ given S (opt L)" will solve for the diameter and round the calculated diameter upward to the next standard pipe size, based on a predefined diameter list. The "→" means the program will go to a new input screen, when the OK tab is pressed. "D↑" means that the program will solve for the diameter and round the diameter upward. "given S" means that the user must input the slope S. "(opt L)" means the user has the option to input the pipe length. When inputting the pipe length, the adjacent checkbox must be checked. When the pipe length is inputted, PipeCalc will calculate the pipe fall and flow travel time.

Solve 11 →D↑S↓ given avail S (opt L)

The "11 →D↑S↓ given avail S (opt L)" will solve for the diameter and round the calculated diameter upward to the next standard pipe size, based on a predefined diameter list. The user must input the available slope. PipeCalc will then decrease or flatten the slope to adjust the relative depth to the inputted Y/D (sizing) using the rounded diameter. The user has the option to input the pipe length.

Solve 12 →D↓S↑ given avail S (opt L)

The "12 →D↓S↑ given avail S (opt L)" will solve for the diameter and round the calculated diameter downward to a standard pipe size, based on a predefined diameter list. The user must input the available slope. PipeCalc will then increase or <u>steepen</u> the slope to adjust the relative depth to the inputted Y/D (sizing) using the rounded diameter. The user has the option to input the pipe length.

<u>Solve 13 →D↑ given L and fall, 14 →D↑S↓ given L and avail fall, and 15 →D↑S↓ given L and avail fall</u>

Solve 13 →D↑ given L and fall, Solve 14 →D↑S↓ given L and avail S, and Solve 15 →D↑S↓ given L and avail S are similar to the previous solve options, except that the pipe length and fall are inputted in lieu of the slope.

<u>Pipe length option</u>

To enable the pipe length option, check the box next to variable L and enter the pipe length and select the units. When the pipe length is entered, the calculator will calculate the flow time.

<u>Diameter list</u>

To round the calculated diameter, the use must select one of the predefined pipe diameter lists. The diameter lists can be view by Solve 09 →view pipe diameter list.

The diameter lists were created from various tables, nomographs and slide rules for concrete and clay pipes. The sizes may not be representative of the actual common available sizes. Secondary pipe sizes may or may not be included in the diameter list. Also, the pipe lists are based on the conversion of British Imperial pipe sizes to Metric sizes and are not based on non-Imperial or international Metric sizes.

The diameters in "US English1, in" are generally from the 2011 ACPA Concrete Pipe Design Manual. However, the 39 in diameter was added to the list. (RCP diameters greater than roughly 84 inches are often cast on-site.)

The diameters in "US Soft Metric1, rnd 5 mm" list are English diameters that were rounded to 5 mm multiples, using Excel's MROUND function.

The diameters in "US Soft Metric1, rnd 10 mm" list are English diameters that were rounded to 10 mm multiples, using Excel's MROUND function. This list was based on the rounded soft Metric diameters used in Table 7-7 in the 2009 FHWA HEC-22 Urban Drainage Design Manual. Table 7-7 uses a 680 mm pipe for a 27 in pipe, which appears to be an error. Whereas, PipeCalc uses a 690 mm diameter for a 27 in pipe. Also, the PipeCalc list includes a 990 mm diameter for a 39 in pipe that is not included in Table 7-7.

When using <u>rounded</u> soft metric diameters, the calculations will be a bit off, because the actual diameter is slightly different from the rounded diameter. This is particularly noticeable when solving for the slope. PipeCalc does allows for some mixed unit calculations. So, one can use the exact diameter in inches in a Metric calculation. This is similar to some storm drainage software that also allows mixed unit calculations.

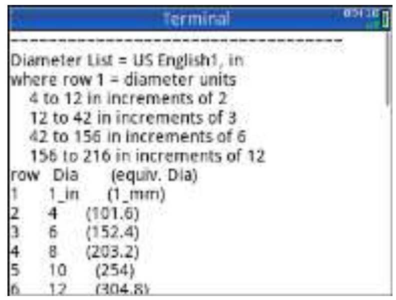
The diameters in "US Hard Metric1 (1995), mm" list were calculated by the expression US English1 (in) diameters times 25 mm. This list was based on the hard Metric diameters used in Table 7-7 in the outdated 1996 FHWA HEC-22 Urban Drainage Design Manual Metric on page 7-24, with the exception that PipeCalc's hard metric diameters were not rounded. The rounding of the diameters in the outdated Table 7-7 was probably an error, as the UK and Canada did not round their hard metric diameters. The "US Hard Metric1 (1995), mm" diameter list is generally not used, because to my knowledge, pipes with hard metric diameters are not available in the US.

On a hydraulic slide rule, when solving for the diameter, the user can see multiple (D,S) solutions at a glance. The user then selects a D and aligns the available S to be opposite the selected D. PipeCalc does not show the family of (D,S) solutions. To see other solutions on PipeCalc, the user must run the program again, switch to the flowrate equation, enter a new D and solve for S.

Minimum diameter

The minimum diameter is based upon the diameter list. The user must enter the row number of the minimum diameter, instead of the diameter. For example, the row number for a minimum diameter of 8 inch on the US English1 list is 4. Therefore, 4 is entered into the min dia row num box.

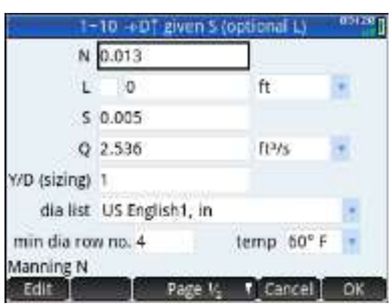
Row 4 = 8 in

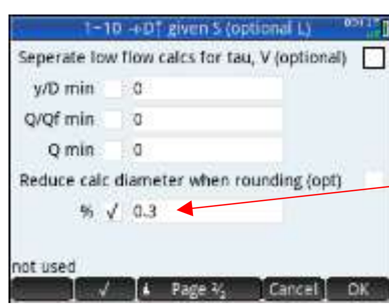


Reduce calculated diameter when rounding option

The *reduce calculated diameter when rounding* option allows the user to enter a percentage from 0 to 2 percent that is applied to the calculated diameter when rounding the diameter. When using PipeCalc to determine the diameter on old pipe designs that were calculated with slide rules or pipe sizing charts, the PipeCalc auto sizing program occasionally gave a larger diameter. For example, if the calculated diameter was 12.03 in, the PipeCalc D↑ auto sizing program would round the diameter upward to 15 in. In contrast, a person using a pipe sizing chart or hydraulic slide rule would use common sense and round the calculated diameter downward to 12 in, because the calculated diameter is very close to 12 in. To replicate this process with PipeCalc, the user can check the rounding checkbox and enter a percentage, say 0.3 percent. PipeCalc will then reduce the 12.03 calculated diameter by 0.3% to 11.994 in. The program would then round the 11.994 value upwards to 12 in.

Similarly, when using a 0.3 percentage, a calculated diameter of 84.25 in would be rounded down to 84 in. Depending upon the flowrate and slope, the actual relative depth Y/D can be 0.005 higher than the design relative depth. If being a small amount over the design Y/D is a concern, you should turn off the reduce calculated diameter option and let the calculated diameter round upward, or steepen the slope in order to use the smaller diameter.





The reduce calculated diameter rounding option is only available for Solve 10 →D↑ given S (opt L) and Solve 13 →D↑ given L & Fall on the flowrate equations.

```
----------------------------------
01 Manning Flowrate Eq n=const
10 Solve →D↑ given S (optional L)
 ▹ Manning N = 0.013
 ▹ slope S = 0.005
   slope ratio = 1 : 200
 ▹ flowrate Q = 2.536_(ft^3/s)
   Q/Qf = 1.0067
 ▹ pipe sized for Y/D = 1
   relative depth Y/D = 0.82584✱
   depth Y = 9.9101_in
 ▹ dia rounding adj (%) = 0.3
   calculated diameter = 12.03_in
   calc diameter for rounding = 11.994_in
   diameter D = 12_in✱ (round up)
 ▹ dia. list = US English1, in
   minimum diameter = 8_in
 ▹ minimum diameter row no. = 4
 ▹ water temp = 60° F
   ----
   velocity V = 3.6556_(ft/s)✱
   V/Vf = 1.1397
   V head = 0.20768_ft
   pressure head = 0.82584_ft
   shear stress τ = 0.09485_(lbf/ft²)
   shear stress τ = 4.5414_Pa
   froude1 no. = 0.67389
   (equivalent KS = 1.5929_mm)
Q full = 2.5191_(ft^3/s)   y/D = 1 & 0.81963
Q peak = 2.7099_(ft^3/s)   y/D = 0.93818
V full = 3.2075_(ft/s)   y/D = 1 & 0.5
V full head = 0.15988_ft
V peak = 3.6566_(ft/s)   y/D = 0.81281
A full = 0.7854_ft^2
critical relative depth Yc/D = 0.68238
critical depth Yc = 8.1885_in
Reynolds no. (KS1) = 365.48E3
kin visc VK = water 60°F = 12.170E-6_(ft^2/s)
density ρ = water 60°F = 1.9383E0_(slug/ft^3)
Notes
• The calculation of τ uses the approximate
equation, where sin(θ)=S.
```

Reduced calculated diameter output.

If I recall correctly, some people used 5 percent, but this was for sizing pipes for full flow, a long time ago, in order to take advantage that a pipe can flow greater than Q full. Further, I think they applied the percentage to Q not D. If you want to do this with PipeCalc, you would not use the reduce diameter percent. Instead, you would set y/D (sizing) to 0.9 or some other number. This method is easier to do on a NCPI hydraulic slide rule, where you would just set y/D = 0.9 on the liquid depth to pipe diameter scale and align it to be opposite Q on the Q scale. Keep in mind that the general practice is to not size pipes greater than full flow.

For those who want to use the smaller pipe but still maintain the full flow requirement, you would need to steepen the slope. On PipeCalc, you can (1) use the sub-program D↓S↑, which rounds the diameter downward and then steepens the slope, or (2) manually solve for the new slope using the flowrate equation. To manually solve for the new slope, you would (1) solve for the calculated diameter, and (2) rerun the program and replace the calculated diameter the round down diameter, and then solve for the steepened slope.

On a NCPI hydraulic slide rule, you would size the pipe normally. For sizing pipes for full flow, set y/D = 1 on the liquid depth to pipe diameter scale and align it to be opposite the design Q on the Q scale. Then, on the slope and diameter paired scales, find the available slope and observe the corresponding calculated diameter. If the calculated diameter is between two standard size diameters, use the smaller diameter. You would then use the corresponding slope opposite the smaller diameter.

Auto pipe sizing sub-program does not solve for the 2nd Y/D solution

If there are two Y/D solutions, the auto pipe sizing sub-program will always return the lower solution, and will make no reference to the 2nd Y/D solution.

In contrast, when using the flowrate equation and solving for Y/D, if there are two Y/D solutions, both solutions will be returned.

3.5. Example problem of D↑ for the flowrate equation

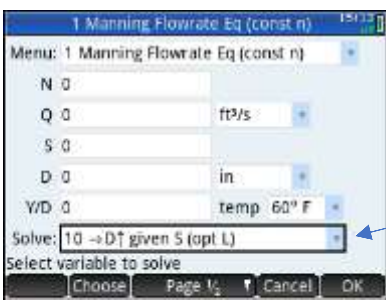
For a discharge of 3.9 MGD, determine the required diameter of pipe, whose slope is 0.10 feet per hundred and roughness coefficient is 0.013 for the Manning equation. Also, determine the velocity at the 3.9 MGD discharge rate and at a 0.9 MGD discharge rate. Assume the minimum diameter is 8 in. Size the pipe for full flow. (answer D = 24 in. y/D = 0.70. V = 2.5 ft/s. At 0.9 MGD, y/D = 0.30 and V = 1.8 ft/s.)

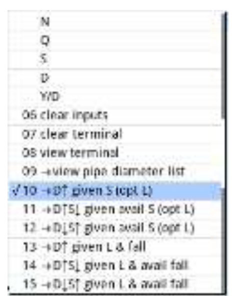
This problem is based on the example on the back of the Field's hydraulic slide rule. The diameter on the Field's slide rule is a little different than the diameters on PipeCalc.

Solution using PipeCalc

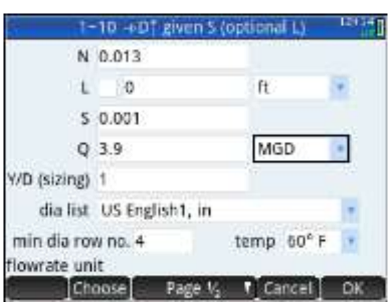
If necessary, switch to the Manning Flowrate (const n) program.

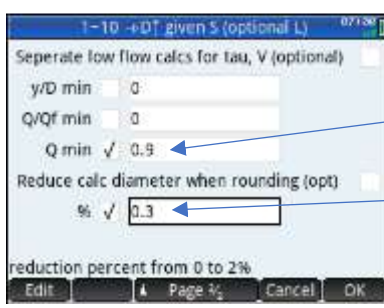
On the Manning Flowrate (const n) program input screen, select solve 10 →D↑ given S (opt L) and press the OK tab.





On the input screen for Solve 10 →D↑ given S (opt L), enter the input values as shown below. Then press the OK tab.





Enter the low flowrate using the same units as Q on page 1.

Use 0.3% to simulate a slide rule calculation. In the old days, a higher percentage would be used.

The program displays the answer on the Print Terminal.

```
-----------------------------------
01 Manning Flowrate Eq n=const
10 Solve →D↑ given S (optional L)
 ▹ Manning N = 0.013
 ▹ slope S = 0.001
   slope ratio = 1 : 1000
 ▹ flowrate Q = 3.9_(MgalUS/d)
   Q/Qf = 0.84354
 ▹ pipe sized for Y/D = 1
   relative depth Y/D = 0.70404✱
   depth Y = 16.897_in
 ▹ dia rounding adj (%) = 0.3
   calculated diameter = 22.516_in
   calc diameter for rounding = 22.449_in
   diameter D = 24_in✱ (round up)
 ▹ dia. list = US English1, in
   minimum diameter = 8_in
 ▹ minimum diameter row no. = 4
 ▹ water temp = 60° F
   ----
   velocity V = 2.5528_(ft/s)✱
   V/Vf = 1.1211
   V head = 0.10128_ft
   pressure head = 1.4081_ft
   shear stress τ = 0.03702_(lbf/ft²)
   shear stress τ = 1.7723_Pa
   froude1 no. = 0.39556
   (equivalent KS = 1.3671_mm)
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 full head = 0.08057_ft
V peak = 2.5959_(ft/s)   y/D = 0.8128
A full = 3.1416_ft^2
Low flow calcs for Q min = 0.9_(MgalUS/d)
  V = 1.7643_(ft/s)
  shear stress τ = 0.02127_(lbf/ft²)
  shear stress τ = 1.0182_Pa
  Y/D = 0.29907
  Q/Qf = 0.19466
critical relative depth Yc/D = 0.43441
critical depth Yc = 10.426_in
Reynolds no. (KS1) = 498.03E3
kin visc VK = water 60°F = 12.170E-6_(ft^2/s)
density ρ = water 60°F = 1.9383E0_(slug/ft^3)
Notes
• The calculation of τ uses the approximate
equation, where sin(θ)=S.
```

3.6. Solve D↑ S↓ for the flowrate equation

The Solve 14 →D↑ S↓ given L & avail fall means solve D (round up) and flatten the available slope, when given L and the available fall. The input parameters are similar to the previous section, except the slope is represented by L and fall.

The Solve 14 →D↑ S↓ given L & avail fall sub-program does not have a *reduce calculated diameter when rounding* option. If the user wants to round the calculated diameter downward, it would have to be done manually.

Example problem

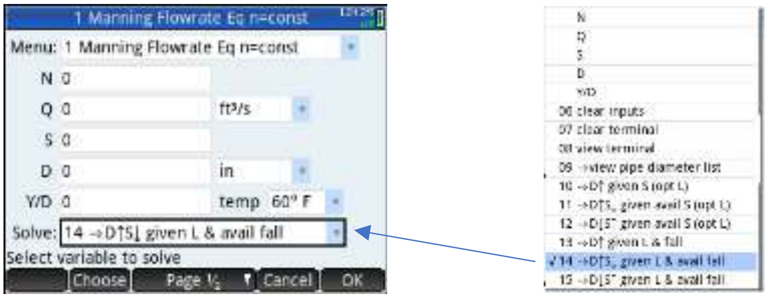
A pipe is to be 700 ft long and is to discharge 30 cubic ft per sec. The maximum available fall is 2.5 ft. (a) What is the necessary size and fall of the pipe, if it is to run 0.8 full, assuming N = 0.015? Use the Manning's equation with a minimum diameter of 8". (b) What would be the velocity and time of flow?

This problem is based on the example in the instructions for a Nordell Slide Rule for Circular Conduits that used the Kutter equation. The answers using the Kutter slide rule were D = 36 in, fall = 2 ft, V = 5 ft/s, and flow time = 2.32

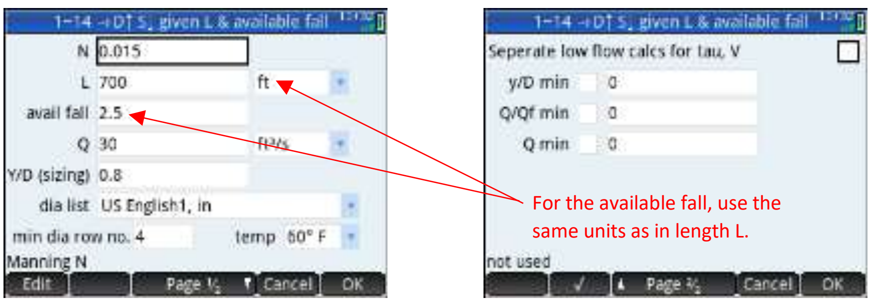
min. The pipe is flowing close to the equivalent full flow depth, so the answers using the Kutter's equation should be close to the answers using the Manning's equation. The K&E version of the Nordell slide rule was manufactured from 1911 to 1922.

Solution using PipeCalc

On the Manning Flowrate (const n) program, select Solve 14 →D↑S↓ given L & avail fall and press the OK tab.



On the input screen for Solve 14 →D↑S↓ given L & avail fall, enter the input values as shown below. Then press the OK tab.



The program displays the answer on the Print Terminal.

```
-----------------------------------
01 Manning Flowrate Eq n=const
14 Solve →D↑ S↓ given L & available fall
 ▹ Manning N = 0.015
 ▹ length L = 700_ft
 ▹ fall (available) = 2.5_ft
   fall = 1.9736_ft✶ (flatten)
   slope S (available) = 0.00357
   slope S = 0.00282✶ (flatten)
   slope ratio = 1 : 354.69
 ▹ flowrate Q = 30_(ft^3/s)
   Q/Qf = 0.97747
 ▹ pipe sized for Y/D = 0.8
   relative depth Y/D = 0.8✶
   depth Y = 28.8_in
   calculated diameter = 34.439_in
   diameter D = 36_in✶ (round up)
 ▹ dia. list = US English1, in
   minimum diameter = 8_in
 ▹ minimum diameter row no. = 4
 ▹ water temp = 60° F
   ----
   velocity V = 4.9487_(ft/s)✶
   V/Vf = 1.1397
   V head = 0.38058_ft
   pressure head = 2.4_ft
   flow travel time = 2.3575_min✶
   (flow travel time full = 2.687_min)
```

(cont.)

shear stress τ = 0.16045_(lbf/ft²)
shear stress τ = 7.6825_Pa
froude1 no. = 0.54895
(equivalent KS = 3.7148_mm)
Q full = 30.692_(ft^3/s) y/D = 1 & 0.81963
Q peak = 33.015_(ft^3/s) y/D = 0.93818
V full = 4.342_(ft/s) y/D = 1 & 0.5
V full head = 0.29298_ft
V peak = 4.95_(ft/s) y/D = 0.8128
A full = 7.0686_ft^2
critical relative depth Yc/D = 0.59152
critical depth Yc = 21.295_in
Reynolds no. (KS1) = 1.4843E6
kin visc VK = water 60°F = 12.170E⁻6_(ft^2/s)
density ρ = water 60°F = 1.9383E0_(slug/ft^3)
Notes

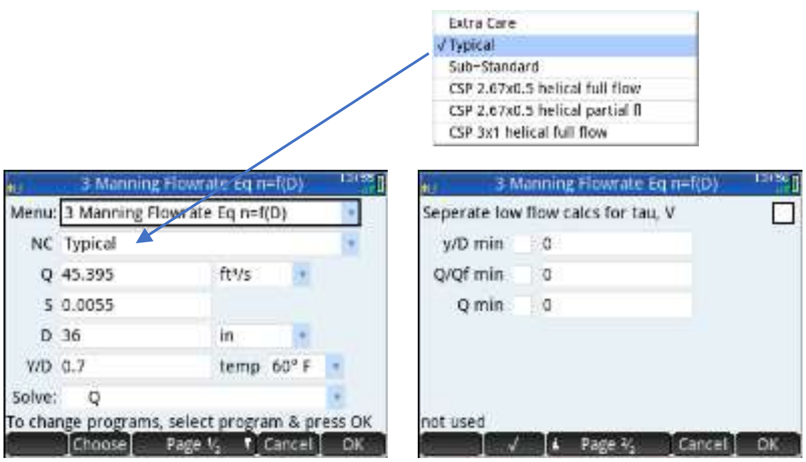
- The calculation of τ uses the approximate equation, where sin(θ)=S.

3.1. Manning n = f(D) programs

General

In the Manning Flowrate and Velocity n=f(D) programs, the n value varies with diameter, but is constant with depth. The term n=f(D) means n is a function of the diameter. In contrast, in the Manning (n=const) programs, the n value is constant with both diameter and depth.

In the Manning n = f(D) programs, the variable NC means "variable N pipe condition" for lack of a better name. The NC variable can be thought of as a list of N values for various pipe diameters.



Extra Care, Typical, and Substandard NC pipe conditions for Manning n=f(D)

The Extra Care, Typical, and Substandard NC pipe conditions are based on the n values listed in the 2007 ASCE Manual 60, Table 5-2, page 134. Only a few n values are listed in the ASCE Manual, and these values were rounded to 3 digits. The extra care values had to be recalculated for each diameter using the Colebrook-White and Manning (const n) programs for ks = 0.3 mm, V = 2 ft/s, y/D = 1, and water temp = 60°F. The (D,n) values were plotted on Excel and several polynomial regression equations were used to represent graph of n=f(D). The regression equations are accurate to 8 or 10 digits. This level of accuracy was used to make the regression equations appear as being continuous over the range of the diameters.

The Typical and Substandard NC pipe conditions are calculated by multiplying the extra care n values by a factor of 1.15 and 1.3, respectively.

CSP 2.67x0.5 in helical NC pipe conditions for Manning n=f(D)

CSP 2.67x0.5 helical full flow and CSP 2.67x0.5 helical partial flow NC pipe conditions are based on Figure B.3, entitled *Manning's n versus diameter for corrugated metal conduits*, 2012 FHWA Hydraulic Design of Highway Culverts, 3rd ed., page B.5. Two regression equations are used to represent the graph of D versus N for the CSP 2.67x0.5 helical full flow. The n values for CSP 2.67x0.5 helical partial flow NC pipe condition are obtained by multiplying the full flow n values by 1.11.

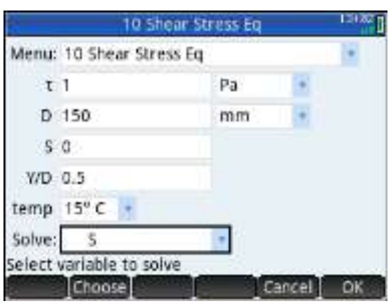
The graph of D versus N has a diameter range of 0.3 m < D < 3.6 m. If the diameter is less than 0.3 m, the program uses n = 0.01099. If the diameter is greater than 3.6 m, the program uses n = 0.02182 (approx). This was necessary to make the n=f(D) function appear as being continuous, when using the program to solve for the diameter.

CSP 3x1 in helical NC pipe conditions for Manning n=f(D)

CSP 3x1 helical full flow NC pipe condition is based on Table 4.9, Values of Coefficient of Roughness (n) for Standard Corrugated Steel Pipe, AISI Modern Sewer Design 1999. There is no partial flow NC pipe condition.

3.2. Solve S using the shear stress equation

Using the tractive force method, calculate the gradient of a 150 mm pipe required to reach a critical shear stress of 1 N/m² when the pipe runs half full. (answer S = 0.0269, approx. 1 : 370)




```
------------------------------------
10 Shear Stress Eq
03 Solve: S
  ▹ shear stress τ = 1_(N/m²)
  ▹ diameter D = 150_mm
    slope S = 0.00272✶
    slope ratio = 1 : 367.42
  ▹ relative depth Y/D = 0.5
  ▹ water temp = 15° C
density ρ = 999.10ᴇ0_(kg/m^3)
Notes
• Uses approx. τ eq, where sin(θ)=S.
```

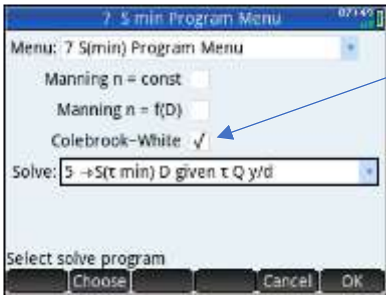
3.3. Solve S(τ min) where y/D min is given

The program 7 *S min Program Menu* has three $S_{v\ min}$ and three $S_{\tau\ min}$ sub-programs listed in the Solve input box. Before running a sub-program, one of the three flowrate equations must be checked.

On some of the programs, the user must input either y/D or Q/Qf. The checkbox next to the input box must be checked to input y/D or Q/Qf.

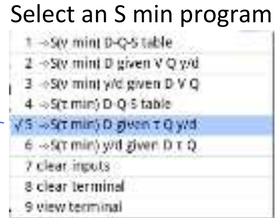
PipeCalc only checks the value of y/D and Q/Qf to see to see if it is a valid number. PipeCalc does not check to see if the value is appropriate. So, inappropriate values for S min calculations, such as y/D = 1 or Q/Qf = 1.05, can be inputted. For Q/Qf inputs, PipeCalc will convert Q/Qf to y/D, and base all calculations on y/D. For some Q/Qf inputs, there can be two y/D solutions. For the S min programs, PipeCalc will select the lower y/D solution.

S min Program Menu

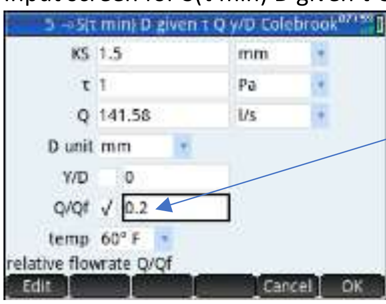


Check one of the flowrate equations.

Select an S min program then press the OK tab



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



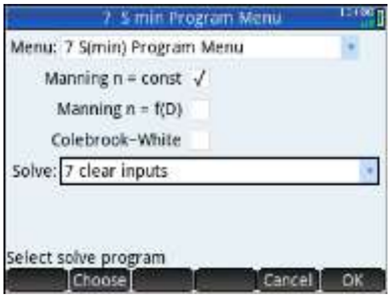
Check Q/Qf, and input the value.

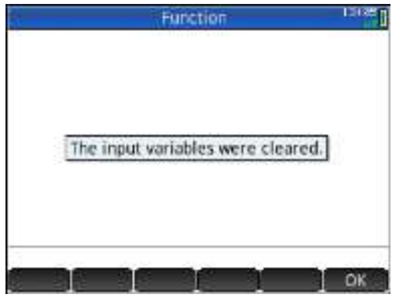
Problem

Given an average flow of 2.25 l/s, and a maximum flow of 6.25 l/s, determine the slope and pipe diameter required for a minimum tractive force of 1 Pa and for a minimum y/D = 0.2 and a maximum y/D = 0.7. Manning's roughness = 0.013. Minimum diameter = 100 mm. Assume water at 20°C.

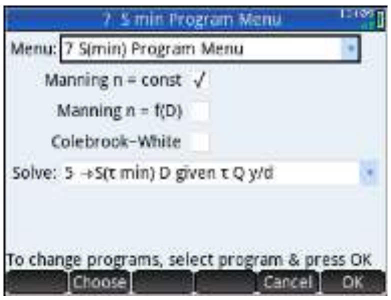
(answer D = 150 mm and S = 0.39%)

This problem involves two calculations, (1) determine the slope for the minimum shear stress, and (2) determine the diameter using the slope for minimum shear stress. It is recommended that the inputs be cleared at the start of the chain calculation. Go to the 7 S(min) Program Menu. In the Solve box, select "clear inputs" and press the OK tab. A message box will be displayed that the input variables were cleared. Press the message box OK tab to continue with the S(min) Program Menu.

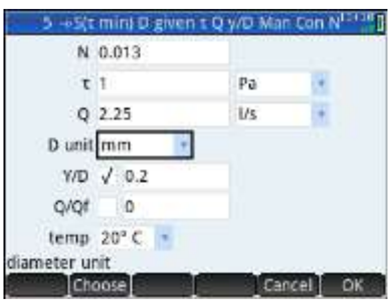




The next step is to run the Solve 5 →S(τ min) D given τ Q y/d. Checkbox the Manning (const n) equation. Select *5 →S(τ min) D given τ Q y/d* in the Solve box and press the OK tab.



On the input screen for Solve 5 →S(τ min) D given τ Q y/d, enter the data as shown. Then press the OK tab.



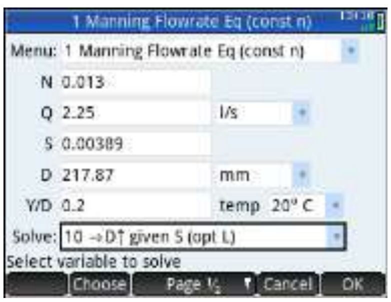
The print terminal displays the results with the minimum slope. Note that the diameter is for minimum flow and needs to be recalculated for the maximum flow.

```
----------------------------------
07 S(min) Programs
05 Solve →S(τ min) D given τ Q y/D
Manning's Eq n=const
  ▹ Manning N = 0.013
  ▹ shear stress τ = 1.0_(N/m²)
    velocity V = 0.42391_(m/s)
    V/Vf = 0.61506
  ▹ flowrate Q = 2.25_(l/s)
    Q/Qf = 0.08757
    slope S = 0.00389✱
    slope ratio = 1 : 257.19
    diameter D = 217.87_mm✱(a)
  ▹ relative depth Y/D = 0.2
    central angle θ = 1.8546_rad
    depth Y = 43.573_mm
  ▹ water temp = 20° C
```

(cont.)

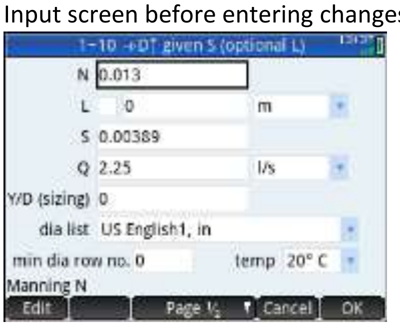
---
froude no. = 0.7757
(equivalent KS = 1.5671_mm)
area A = 0.00531_m^2
hydraulic radius HR = 0.02627_m
wetted perimeter WP = 0.20203_m
top width TW = 0.17429_m
Q full = 25.693_(l/s)   y/D = 1 & 0.81963
Q peak = 27.638_(l/s)   y/D = 0.93818
V full = 0.68921_(m/s)   y/D = 1 & 0.5
V peak = 0.78572_(m/s)   y/D = 0.8128
A full = 0.03728_m^2
critical rel. depth Yc/D = 0.17571
critical depth Yc = 38.281_mm
Reynolds no. (KS1) = 44.415E3
k viscosity VK = water 20°C = 1.0030E-6_Pa
density ρ = water 20°C = 998.21E0_(kg/m^3)
Notes
• The calculation of τ uses the approximate equation, where sin(θ)=S.
(a) D is generally not used, as the pipe diameter is usually sized by Q max.

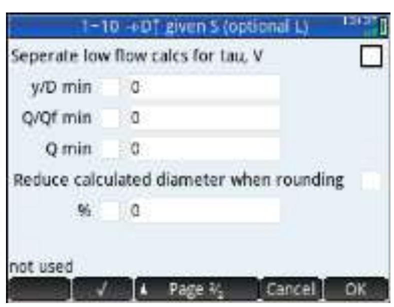
Run the program again. Switch to the Manning Flowrate (const n) program. Select Solve 10 →D↑ given S (opt L), and press the OK tab.



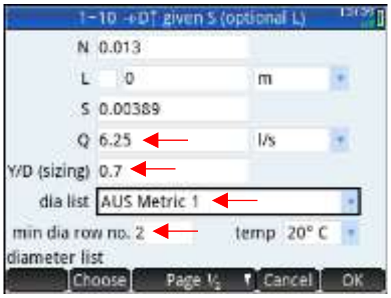
On the input screen for Solve 10 →D↑ given S (opt L), the previous values for N, Q and S are shown. Enter new values to solve for the diameter using Q max. Change Q1 to 6.25. Enter Y/D for sizing = 0.7. Select AUS Metric 1 diameter list. Enter 2 for the minimum diameter row number. Input the low flow rate on page 2 of the input screen. Checkbox and input the reduce calc diameter percent as shown. Then press the OK tab.

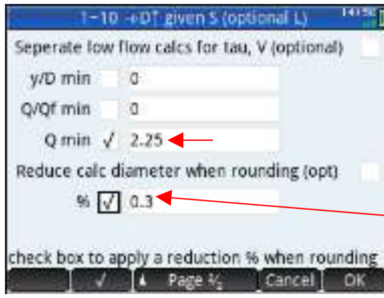
Input screen before entering changes





Input screen after entering changes. When all changes have been entered, press the OK tab.





Round downward if the calculated diameter is 0.3 % or less above the round down diameter.

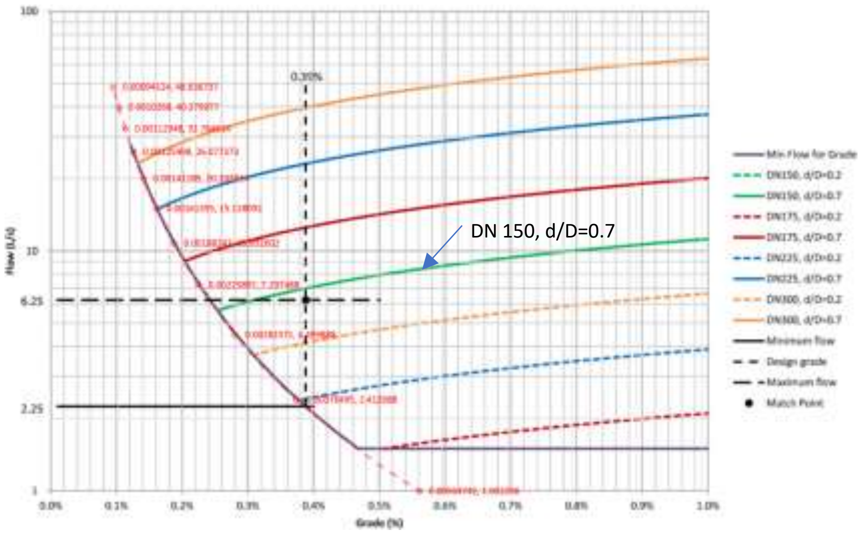
The results are displayed on the print terminal.

```
-----------------------------------
01 Manning Flowrate Eq n=const
10 Solve →D↑ given S (optional L)
 ▹ Manning N = 0.013
 ▹ slope S = 0.00389
   slope ratio = 1 : 257.19
 ▹ flowrate Q = 6.25_(l/s)
   Q/Qf = 0.65814
 ▹ pipe sized for Y/D = 0.7
   relative depth Y/D = 0.59202✱
   depth Y = 88.803_mm
 ▹ dia rounding adj (%) = 0.3
   calculated diameter = 137.05_mm
   calc diameter for rounding = 136.64_mm
   diameter D = 150_mm✱ (round up)
 ▹ dia. list = AUS Metric 1
   minimum diameter = 100_mm
 ▹ minimum diameter row no. = 2
 ▹ water temp = 20° C
   ----
   velocity V = 0.57369_(m/s)✱
   V/Vf = 1.0676
   V head = 0.01678_m
   pressure head = 0.0888_m
   shear stress τ = 1.5744_Pa
   shear stress τ = 0.03288_(lbf/ft²)
   froude1 no. = 0.67394
   (equivalent KS = 1.6314_mm)
Q full = 9.4964_(l/s)    y/D = 1 & 0.81963
Q peak = 10.215_(l/s)    y/D = 0.93818
V full = 0.53739_(m/s)    y/D = 1 & 0.5
V full head = 0.01472_m
V peak = 0.61264_(m/s)    y/D = 0.8128
A full = 0.01767_m^2
Low flow calcs for Q min = 2.25_(l/s)
   V = 0.44006_(m/s)
   shear stress τ = 1.0577_Pa
   shear stress τ = 0.02209_(lbf/ft²)
   Y/D = 0.33128
   Q/Qf = 0.23693
critical relative depth Yc/D = 0.48155
critical depth Yc = 72.232_mm
Reynolds no. (KS1) = 94.635E3
kin visc VK = water 20°C = 1.0030E-6_Pa
density ρ = water 20°C = 998.21E0_(kg/m^3)
Notes
• The calculation of τ uses the approximate
equation, where sin(θ)=S.
```

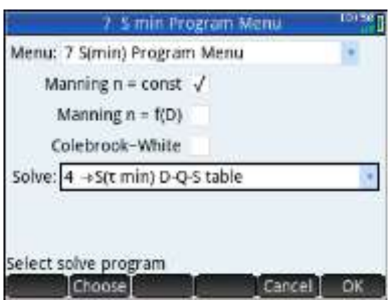
The use of the new diameter caused the shear stress to increase a small amount above the initial design value. Observe that the relative depth increased a large amount above the design value (from 0.2 to 0.33). For small diameter pipes, the small error with the shear stress is considered acceptable. The design would typically stop at this point.

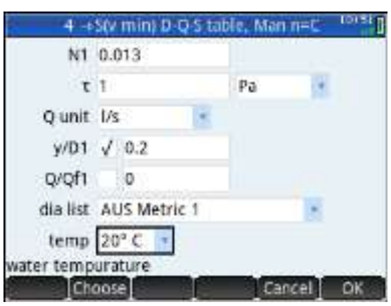
However, as the diameter is now known, the minimum slope can be recalculated using Solve 6 S(τ min) y/d given D τ Q. With the new slope known, the Manning flowrate eq can be used to calculate y/D, using Q max and Q min. Alternatively, the pipe can by sized using Solve 10 →D↑ procedure using Q max and Q min. Either procedure should yield τ = 1 Pa for the low flow.

Tractive force design chart (grade as %)
Based on τ = 1 Pa; min d/D = 0.2, max d/D = 0.7
Christchurch, NZ



As a check, data from PipeCalc's S(τ min) D-Q-S table was plotted over the design chart (in red). The data from the S(τ min) D-Q-S table is the same as the chart's Min Flow for Grade.





----
07 S(min) Program Menu
04 Solve →S(τ min) D-Q-S table
Manning's Eq n=const
N = 0.013
shear stress τ = 1_(N/m²)
y/D min = 0.2
dia. list = AUS Metric 1
D units = 1_mm
Q units = 1_(l/s)
density ρ = water 20°C = 998.21_(kg/m^3)

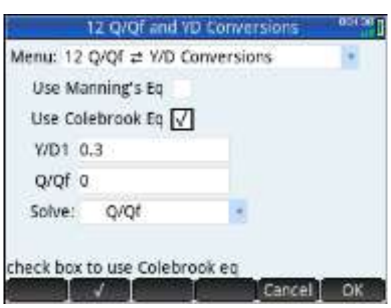
D	Q min	S min
100	0.4163	0.00847
150	1.0022	0.00565
225	2.4127	0.00377
300	4.4999	0.00282
375	7.2975	0.00226
450	10.833	0.00188
525	15.128	0.00161
600	20.204	0.00141
675	26.077	0.00126
750	32.765	0.00113
825	40.28	0.00103
900	48.637	0.00094
975	57.847	0.00087
1050	67.923	0.00081
1125	78.874	0.00075
1200	90.712	0.00071
1275	103.45	0.00066
1500	147.11	0.00057
1650	180.85	0.00051
1800	218.37	0.00047
1950	259.73	0.00043
2100	304.96	0.0004
2250	354.13	0.00038
2400	407.28	0.00035
2550	464.45	0.00033
2700	525.69	0.00031
2850	591.02	0.0003
3000	660.49	0.00028

3.4. Q/Qf conversions

Problem

For the Colebrook-White equation, if y/D = 0.3, what is Q/Qf?

Solution



-----------------------------------12
Q/Qf ⇄ Y/D Conversions
02 Solve Q/Qf
Colebrook−White equation
▹ relative depth Y/D = 0.3
relative flowrate Q/Qf1 = 0.19989✶
• The Q/Qf⇄y/D conversion is an approx. calculation using the basic case described in Wallingford and Barr's Table C1, 2008.

Comparison

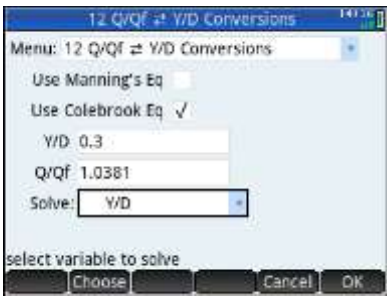
PipeCalc's Q/Qf ⇆ Y/D Conversions	0.19989
Wallingford and Barr's Table C1, 2008	0.200
Franke's 1957 equation	0.1989

When solving some problems for S and D, if the user specifies Q/Qf for the Colebrook equation, PipeCalc converts Q/Qf to y/D using an approximate equation. For the Colebrook-White equation, the Q/Qf ⇆ Y/D Conversions is not stable or constant when the slope and other parameters are varied. Therefore, the Q/Qf ⇆ Y/D conversions only give an approximate answer.

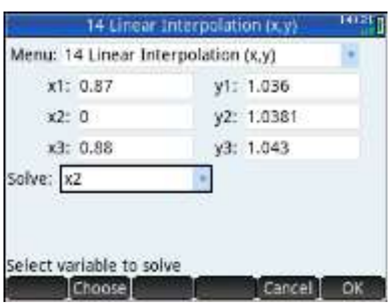
Example 2

Given Q/Qf = 1.0381, find y/D for the Colebrook-White Equation

(answer from Wallingford and Barr Table C1: y/D1 = 0.873 by interpolation and y/D2 = 0.99)



----
12 Q/Qf ⇄ Y/D Conversions
01 Solve y/D
Colebrook–White equation
relative depth Y/D1 = 0.87327✱ 1st solution
relative depth Y/D2 = 0.99002✱ 2nd solution
▹ relative flowrate Q/Qf1 = 1.0381
● The Q/Qf⇄y/D conversion is an approx. calculation using the basic case described in Wallingford and Barr's Table C1, 2008.



----
14 Linear Interpolation (x,y)
x1 = 0.87 y1 = 1.036
x2 = 0.873✱ y2 = 1.0381
x3 = 0.88 y3 = 1.043

4. Comments

4.1. Manning's n=const

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 BG units, as necessary. Because of this, the program's results will be slightly different from other programs that use a rounded Manning's k value of 1.49. The use of the exact Manning's k value not only affects the value of Q and V, but also affects the value of the depth, area, and most other Manning's parameters.

In version i, many of the Manning's equations were solved using fsolve. However, the program would not work when using the CAS screen using software version 2.1.14603 (2021 12 02). So, fsolve was replaced with the bisection method that was used for the Colebrook-White equation. This method is really not the best method to solve Manning's equation. While the program now works on the CAS screen, it is suggested that the program only be run from the Home screen.

4.2. Manning's Variable N Equation where n=f(D)

Initially, the program used the Colebrook-White and Manning's equation subroutines to determine for the exact value of n for the ASCE (2007) pipe conditions. This method worked fine on the HP Prime virtual calculator running on a Windows 10 laptop. However, when solving for the diameter on the physical calculator (hardware A), the program took 20 to 40 seconds to determine the diameter. This long time was caused by two nested loops, where each loop contained one or more iterative processes.

To speed up the calculation of the n value, the formulas to calculate n were replaced with a polynomial regression equation that directly solved for n, when given the diameter. The regression equation is divided up into 11 splines, and a 4^{th} order polynomial regression equation was determined for each spline.

For the Manning n=f(D) equation, PipeCalc cannot solve for the NC pipe condition. If the velocity profile is measured with a velocity probe or doppler laser, one can calculate the n value with Manning's constant n equation. With the Manning n=f(d) equation, you cannot calculate the actual NC value.

4.3. Colebrook-White Equation

In the older version of PipeCalc, the program used the Colebrook-White partial flow equation from *Design charts for water supply and sewerage*, Standards Australia, AS 2200-2006, 2006, Amendment 1, page 5, where one of the constants in the equation was 14.8. However, the older version of PipeCalc gave slightly different answers for Q and V than listed in Wallingford and Barr's A tables or in design examples for UK storm drainage design software.

To make PipeCalc provide answers closer to the Wallingford and Barr's tables, the aforementioned 14.8 constant was changed to 14.83. The 14.83 constant came from *Applicability of the Colebrook-White Formula to Represent Frictional Losses in Partially Filled Unsteady Pipeflow*, JA Swaffield and S Bridge, Journal of Research of the National Bureau of Standards, UK, Vol. 88, No. 6, Nov-Dec 1983, pp 389-393.

To solve the Colebrook-White partial flow equation, this program uses the bisection method, where F(x)=Q, and where Q is known and can be explicitly solved. For the velocity equation, the program uses F(x)=V, where V is known. This method is very slow and takes about 35 iterations to solve the unknown variable with an allowable error of 1E-10, where the calculator accuracy is 1E-11 or 1E-12 for Home view. This method is a combination of the bisection method with the old trial-and-error method that was used to solve for depth in open channels, when given Q. This numerical method was used, because I was having some intermittent problems with the standard bisection method when solving for the unknown variables. A plot of the unknown variable versus f(x)=0 for the basic case shown an area where the curve approaches very high value and had a very steep slope. Another plot of an unknown variable versus f(x)=0 shown an area where the curve was very flat. I don't know for sure, but I think these areas of the curve were affecting the answers from my numerical method code.

This program does not check to see if the flow parameters are within the range of the Colebrook-White equation.

This program does not use the Swamee–Jain approximate equation.

4.4. Peak Flowrate and Velocity

For the flowrate and velocity programs, the calculation of peak Q and V and the corresponding relative depth Y/D are solved iteratively using a modified bisection method that uses f(x)=Q and f(x)=V with a double bracket interval, where each bracket has a mid-point. This numerical method was adapted from an old lecture video for a 1st semester physics class to numerically find the maximum height of a projectile. The peak flowrate is subsequently used to determine if a pipe is flowing under pressure flow. The relative depth for peak flow and peak velocity are used to define the bisection limits of the flowrate and velocity programs, when solving for the 1st and 2nd Y/D solutions.

4.5. Shear Stress Equation

The shear stress equation for Manning's equation was taken from *PC-Based Simplified Sewer Design* by D Mars, A Sleigh, and K Taylor, Department for International Development, published by the School of Civil Engineering, Univ. of Leeds, London, England, 2001. This publication includes the derivation of the shear stress equations. The same formula derivation or methodology was applied to the Colebrook-White shear stress equation.

4.6. Chain Calculations

This program saves the input values to global variables. Many of the equations share the same input variables. This allows the ability to perform chain calculations with many of the equations. However, the user needs to make sure that values from the prior calculation are relevant to the current calculation. For example, when solving for the relative depth using the velocity equation, the program might return two solutions. When switching to the flowrate equation, the lower solution is transferred to the input screen of the flowrate equation, but the user may have wanted to use the upper solution.

To make chain calculations easier with the Continuity and critical flow equations, this program will zero unused variables in the Continuity and Critical flow equations, after the unknown variable is solved. So, when switching to the flowrate equation, unused variables, such as slope, will show a value of zero.

Some common chain calculations, such as solving for the diameter and rounding the diameter upward to the next standard size, were added to the flowrate equations. These routines are shown in the solve menu (10-15) of the flowrate equations.

The output for the flowrate equations will show a lot of supplemental information. Some of this information, such as velocity V1, will be transferred (shared) with other equations when performing chain calculations.

4.7. Units

Although units can be entered into the program, this program does not solve equations with units. This is due to the fact that the calculator can only solve simple arithmetic equations with units. As a result, this program merely converts the inputted units to SI units, solves the equation using SI values, and converts the SI answer back to the user units.

More specifically, the program takes the inputted values in user units and stores the value and unit parts into unit list variables. The unit list variable contains the MKSA value part, MKSA unit part, user value part, user unit part, and other information. The program then uses the user value and unit parts to calculate the MKSA value part for each unit variable. The MKSA unit part are predefined in the variable declaration. All calculations to solve for the unknown variable are solved using the MKSA value part of the unit variable. In addition, all ancillary and supplemental calculations are solved using the MKSA value part of the unit variable. When all calculations are done, and just before printing the output, the program calculates the user value part for all of the unit variables. To print a value with units, the program prints the expression *user value part * user unit part*.

After the program solves for the unknown variable, the program will calculate and print miscellaneous information, such as the cross-sectional area and hydraulic radius. The units for this supplemental information are not inputted. The program determines the units of the supplemental information based on the units of the inputted flowrate or velocity. In the velocity programs, the units of the flowrate must be inputted, so that the supplemental flowrate information can be calculated and printed in user units.

On a different subject, for an example of a program that does solve equations with units, see HP Solve Equation Library Application Card Owner's Manual, Hewlett Packard, Ed. 2, July 1990. Appendix B, *Equation Library Notes*, discusses some of the problems with working with equations with units. (I never owned an HP-48 calculator or used the equation library card.)

Kinematic Viscosity

The kinematic viscosity values for water were taken from Water Supply and Pollution Control, by W Viessman and MJ Hammer, HarperCollins, 1992, table A.8, page 846. These values are outdated, but this was the only source I could find that listed the kinematic viscosity in both Celsius and Fahrenheit units. These values are different from the values listed in the CRC Handbook of Chemistry and Physics, 95^{th} Ed., 2014-15. I near as I can tell, the physical properties of water have not changed, but the equations used to calculate the kinematic viscosity have changed at least twice over the years.

5. Revisions

5.1. PipeCalc3 version L

The list of program names was modified. Also, the program makes more references to program list.

The clear variable function was revised to include all working variables. Some working variables were not being clear and were causing some calculation problems.

Added NC pipe conditions for helical CSP helical pipe.

Revised more of the error message routines to display the error using a text box instead of the print terminal.

5.2. PipeCalc3 version k

Deleted the program's use of HSeparator and AFormat variables. The program will only revise AAngle, HFormat, and HDigits settings. The program simply uses the existing HSeparator setting specified for the Home screen. The program still changes HFormat to floating, as this setting reduces digit clutter on the print terminal.

For Q/Qf ⇆ Y/D conversions for the Colebrook-White eq., added a procedure to return y/D = 1, if Q/Qf is close to 1. This procedure was accidently deleted in version j.

For the Q/Qf ⇆ Y/D conversions for Manning and Colebrook-White equations, corrected the bisection method limits, where y/D2 was not being calculated if Q was greater than Qf, but less than Qp.

Fixed the error in the flowrate and velocity subroutines, where when solving for Y/D using the bisection method and using the exact Q full or V full values, the program would only return the lower solution. The program will now return both y/D solutions. This was accomplished by modifying test condition for the second y/D solution, where the calculated Q full is reduced by a tiny amount. I think the error was caused by the fact that the bisection method routine is only accurate to 1E-10 and has no rounding provision, while the calculator is accurate to 1E-11 or 1E-12.

The bisection code to solve for Y/D was streamlined.

Added outYD2 to the Vars key variables. This will allow the user access to the 2nd y/D solution, if a 2nd solution exists.

5.3. PipeCalc3 version j

Fixed the problem, where the program worked fine in Home view, but would not run or run properly in CAS view. This required the deletion of the fsolve and EXPR statements. Fsolve was replaced with the bisection method used in the Colebrook-White equations. This method is not a good method to solve Manning's equation, but it was easy to just copy the code from the Colebrook-White equations. When running the program on the CAS screen, the previous information on the print terminal is not saved.

Revised the critical flow equation subroutine. Deleted the checks for pressure flow. Deleted the RETURN statement. Replaced fsolve with the bisection method. The program now gives answers similar to online critical flow calculators.

Fixed the problem with Manning (var n) equation solver, where N was not being calculated.

Fixed the problem with TAU units, where the shear stress was always in metric units in the Manning's velocity programs.

In the main program, deleted the use of AFormat settings.

5.4. PipeCalc3 version i

Corrected error with the Manning flowrate equation solver subroutines, where the program would not find an answer when solving for Y/D, if the exact, 11 digit, Q full was inputted.

Added solve D↓S↑ to the flowrate equations. This procedure will round the diameter downward and steepen the slope.

Fixed error in the Manning (var N) equation solver subroutine, where when solving for D, rN1(1) was not defined.

Revised some error messages to display the error on a message box instead of printing the error on the print terminal. Using a message box will keep the program running, so after pressing the message box OK tab, the program will return to the previous input screen. Also, when clearing the print terminal or changing the number of digits, a confirmation message box will be displayed.

When chaining calculations with the flowrate equation, velocity equation and some S min programs, the program was revised to clear unused N or KS input variables.

5.5. PipeCalc3 version h

Revised program to clear D and S input variables for the S(min) D-Q-S tables.

Corrected bug with the error check when inputting Q/Qf.

For the flowrate program, added statements to clear unused variables, inFall and inLe. If inFall is calculated, added statements to save the calculated values to the input variables.

For Q/Qf ⇆ Y/D conversions, when Q/Qf = 1, the conversion to Y/D gave an error, because the log term in the conversion equation is close to zero. Added a band-aid solution to return y/D = 1, if Q/Qf is close to 1.

The diameter lists for the rounded Metric list had some errors. The diameter lists were revised by rounding the diameters using Excel MROUND to 5 and 10 mm multiples. Also, added US hard metric diameter list.

5.6. PipeCalc3 version g

For the S(min) programs, corrected error in the way Q/Qf was calculated. Also, corrected the way the equivalent Y/D was saved.

5.7. PipeCalc3 version f

Corrected the length unit error with program 1-10.

Revised the processing of the input and conversion to MKSA for some of the input variables.

Revised the check input for zeros subroutine.

Corrected the clear input for the Q conversion program.

Fixed the cancel subroutine for program 3.

Fixed the check for y/D for critical flow.

5.8. PipeCalc3 version e

Fixed the calc of the Froude number for full flow to print "not applicable"

Change the calculator number format from Fixed to Floating.

Corrected the set digits program.

Modified the bisection method code for the Colebrook-White equation subroutines to check if the slope is positive or negative and modified the code to handle either case. This was done to have a consistent code.

Corrected the problem with the viscosity and density inputs. This was done by only entering the water temperature and then calculating both the viscosity and density of the water.

Corrected the error in the Manning (var n) equation solver.

5.9. PipeCalc3 version d

Corrected the y/D (sizing) input flag.

Corrected the print statements for the reduce calc dia when rounding, and the NC input flag.

Corrected the input screen error with programs 3-11 and 5-13.

Revised set accuracy program to handle non-integer inputs.

In the S(v min) programs, corrected Solve D to save D to the input variables.

5.10. PipeCalc3 version c

In the velocity equation, in the process input variables, deleted the input checks for low flow input as the velocity eq program does not have low flow calcs.

Revised the clear input subroutine to include more input variables.