International Journal of Scientific & Engineering Research, Volume 3, Issue 1, January-2012
ISSN 2229-5518

A Simplified Pipeline Calculations Program: Isothermal Gas Flow (2)

Tonye K. Jack

Abstract — and Program Objective -The familiarity and user friendliness of the Microsoft Excel ^{TM} spreadsheet environment allows the practicing engineer to develop engineering desktop companion tools to carry out routine calculations. A Multitask single screen gas pipeline sizing calculation program is developed in Microsoft Excel ^{TM}. Required equations, and data sources for such development is provided.

Index Terms— Isothermal pipeline design, pipe sizing, piping program, gas pipelines, engineering on spreadsheet, spreadsheet solutions.

◆

1 INTRODUCTION

Gas pipelines are employed for meeting various energy needs. Calculations for the design of such gas piping can often involve repetitive calculations whether for simple horizontal straight pipelines or pipelines for complex terrains. Advances in computer applications for piping design have created several off-the-shelf can programs, for which cost might be a limitation to their uses for certain, quick-check calculations. Microsoft Excel ™ with its Visual Basic for Applications (VBA) automation tool can be used to develop a multi - functional single screen desktop tool to carry out such calculations.

2 REQUIRED GENERAL EQUATIONS FOR ISOTHERMAL FLOW

Pipe cross-sections are of Circular types for which the applicable relations are:

Reynolds Number: $$R_e = \frac{\rho VD}{\mu} \quad (1)$$

Velocity: $$V = \frac{Q}{A} \quad (2)$$

Area: $$A = \frac{\pi D^2}{4} \quad (3)$$

Friction factor:

For Laminar Flow, $$f = \frac{64}{R_e} \quad (4)$$

For Turbulent Flow, *f*, is obtained by the Colebrook-White equation. Method of solution described in [1], uses the goal seek option in Microsoft Excel™.

$$\frac{1}{f^{\frac{1}{2}}} = -2Log\left\{\frac{\left(\varepsilon/D\right)}{3.7} + \frac{2.51}{\left(\sqrt{f}\right)R_e}\right\} \quad (5)$$

Flow rate:

$$G = \gamma AV \quad (6)$$

Where,

$$\gamma = P/RT = \rho g \quad (6a)$$

The General Relation for evaluating such gas lines is given by equation (7).

$$P_1^2 - P_2^2 = \frac{G^2RT}{g^2A^2}\left[\left(\frac{fL}{D}\right) + 2Ln\left(\frac{P_1}{P_2}\right)\right] \quad (7)$$

3 FLUID PROPERTIES FUNCTIONS

A database of physical properties of typical piped gases can be developed using Microsoft Excel ™ Functions category. The developed functions are then available as drop down lists in the Functions option of the Toolbar INSERT menu. Yaws, [2], [3], [4] provides density, and viscosity data as functions of temperature.

As an example, the [5], derived curve-fitted gas viscosity relationship for Methane (CH_4), as a function of temperature is:

$$\mu_g = A + BT + CT^2 \quad (9)$$

Where, A= 15.96, B= 0.3439, C=-8.14 E-05
The unit of viscosity is in micro-poise, which can be converted to Ns/m^2 by multiplying by 1E-6:

Thus, the revised equation is:

$$\mu_g = \left(10^{-6}\right)\left(A + BT + CT^2\right) \quad (9a)$$

The temperature, *T*, in "(9)," is in Kelvin (K). The program can be developed to handle temperature data in Centigrade (°C) with a built-in conversion option.

The ALIGNAgraphics [6], structured naming convention for the fluid properties functions described in [1], is applied, i.e.

Name of property_ (temperature)

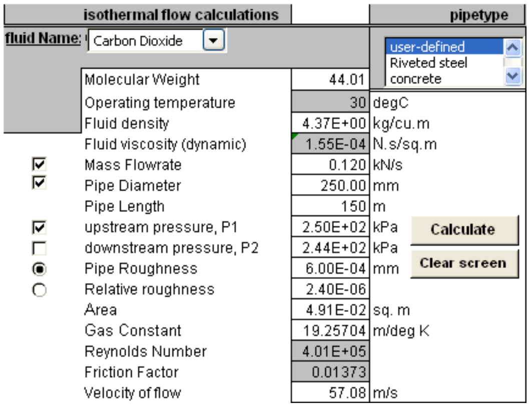
For Methane: **rhoMethane** (temperature)
viscoMethane (temperature)

Where **rhoMethane**, and **viscoMethane** are the function names for Methane gas density and gas viscosity respectively. The program developer could also adopt the chemical formula of the fluid type, particularly in cases of long fluid property names as in some hydrocarbons. Thus, using **Methane** as example, the following gas density function name will apply:

rhoCH4(temperature).

4 APPLICATION EXAMPLE

Carbon Dioxide flows isothermally at 30°C through a horizontal 250 mm diameter pipe at the rate of 0.12kN/s. If the pressure at a *section 1* is 250 kPa, find the pressure at a *section 2*, which is 150 m downstream? Take that: Pipe Roughness = 6 x 10^{-4} m.



fluid Name: Carbon Dioxide

	Molecular Weight	44.01	
	Operating temperature	30	degC
	Fluid density	4.37E+00	kg/cu.m
	Fluid viscosity (dynamic)	1.55E-04	N.s/sq.m
☑	Mass Flowrate	0.120	kN/s
☑	Pipe Diameter	250.00	mm
	Pipe Length	150	m
☑	upstream pressure, P1	2.50E+02	kPa
☐	downstream pressure, P2	2.44E+02	kPa
●	Pipe Roughness	6.00E-04	mm
○	Relative roughness	2.40E-06	
	Area	4.91E-02	sq. m
	Gas Constant	19.25704	m/deg K
	Reynolds Number	4.01E+05	
	Friction Factor	0.01373	
	Velocity of flow	57.08	m/s

Nomenclature

P_1	Upstream pressure (kPa).
P_2	Downstream pressure (kPa).
G	Mass Flowrate (KN/s).
g	Gravity constant (m/s^2).
A	Area (m^2).
f	Friction factor
D	Pipe internal diameter (m)
L	Pipe section length (m).
M	Molecular Weight
γ	Specific weight (kN/m^3).
ρ	Gas density (kN-s^2/m^4).
V	Velocity of flow (m/s).
R	Gas constant (m/degK).
T	Temperature, (°C) or (K)

APPENDIX

Appendix A – Solution Method

From the General Relation – "(7),": i.e.

$$P_1^2 - P_2^2 = \frac{G^2RT}{g^2A^2}\left[\left(\frac{fL}{D}\right) + 2Ln\left(\frac{P_1}{P_2}\right)\right]$$

Let

$$Z = \frac{G^2RT}{g^2A^2} \tag{10}$$

Then,

$$P_1^2 - P_2^2 = \left[\left(\frac{ZfL}{D}\right) + 2ZLn\left(\frac{P_1}{P_2}\right)\right] \tag{11}$$

Or

$$P_1^2 - 2ZLn\left(\frac{P_1}{P_2}\right) = \left[\left(\frac{ZfL}{D}\right) + P_2^2\right] \tag{12}$$

From "(12)," neglecting the second term on the Left-Hand Side, i.e.

$$2ZLn\left(\frac{P_1}{P_2}\right)$$

yields

$$P_2 = \left[P_1^2 - \left(\frac{ZfL}{D}\right)\right]^{\frac{1}{2}} \tag{13}$$

Then use this value of P_2 to replace the P_2 term in the neglected item, and solve for P_2 on the lef-hand side of "(11),".

Repeat for P_1 to obtain:

$$P_1 = \left[\left(\frac{ZfL}{D}\right) + P_2^2\right]^{\frac{1}{2}} \tag{14}$$

Appendix B – A Clip of Excel VBA subroutines for stringing cell values

```
Option Explicit
Dim M As Double, D As Single, d1 As Single, Vel As Single, visco As Sin-
```

```
gle
Dim L As Variant, Rho  As Single, f As Single, A As Single, T As Single
Dim Mw As Single
Sub isothermalpipeType()
   If Sheets("isothermal compressibleFlow").Range("K12") = 1 Then
   Sheets("isothermal compressibleFlow").Range("D13") = ""
   ElseIf 2 <= Sheets("isothermal compressibleFlow").Range("K12") And
Sheets("isothermal compressibleFlow").Range("K12") <= 10 Then
      Sheets("isothermal compressibleFlow").Range("D13") =
Sheets("isothermal compressibleFlow").Range("Q19")
   End If

End Sub

Sub isothermalMolecularWeight()
   If Sheets("isothermal compressibleFlow").Range("K7") = 1 Then
   Sheets("isothermal compressibleFlow").Range("D4") = ""
   ElseIf 2 <= Sheets("isothermal compressibleFlow").Range("K7") And
Sheets("isothermal compressibleFlow").Range("K7") <= 52 Then
      Sheets("isothermal compressibleFlow").Range("D4") =
Sheets("isothermal compressibleFlow").Range("Q17")
   End If
End Sub

'Perform isothermal compressible flow pipe sizing calculations
'Circular pipeline section calculations
Sub Isothermalcircular()

'given M, P1, D, L, viscosity, relative roughness, upstream pressure P2
unknown
If Sheets("isothermal compressibleFlow").Range("K8").Value = True And
Sheets("isothermal compressibleFlow").Range("K9").Value = True And
Sheets("isothermal compressibleFlow").Range("K10").Value = True And
Sheets("isothermal compressibleFlow").Range("K14").Value = 1 Then
   Sheets("isothermal compressibleFlow").Range("D6") =
Sheets("isothermal compressibleFlow").Range("R18")
   Sheets("isothermal compressibleFlow").Range("D13") =
Sheets("isothermal compressibleFlow").Range("R19")
   Sheets("isothermal compressibleFlow").Range("D15") =
Sheets("isothermal compressibleFlow").Range("R24")
   Sheets("isothermal compressibleFlow").Range("D16") =
Sheets("isothermal compressibleFlow").Range("R29")
   Sheets("isothermal compressibleFlow").Range("D19") =
Sheets("isothermal compressibleFlow").Range("R25")
   Sheets("isothermal compressibleFlow").Range("D17") =
Sheets("isothermal compressibleFlow").Range("R30")
   Sheets("isothermal compressibleFlow").Range("R11").GoalSeek Goal:=0,
ChangingCell:=Sheets("isothermal compressibleFlow").Range("R7")
   Sheets("isothermal compressibleFlow").Range("D18") =
Sheets("isothermal compressibleFlow").Range("R31")
   Sheets("isothermal compressibleFlow").Range("D12") =
Sheets("isothermal compressibleFlow").Range("R28")
   Sheets("isothermal compressibleFlow").Range("D4") =
Sheets("isothermal compressibleFlow").Range("Q17")

'given M, P1, D, L, viscosity, absolute roughness, upstream pressure P2
unknown
ElseIf Sheets("isothermal compressibleFlow").Range("K8").Value = True
And Sheets("isothermal compressibleFlow").Range("K9").Value = True
And Sheets("isothermal compressibleFlow").Range("K10").Value = True
And Sheets("isothermal compressibleFlow").Range("K14").Value = 2 Then
   Sheets("isothermal compressibleFlow").Range("D6") =
Sheets("isothermal compressibleFlow").Range("S18")
   Sheets("isothermal compressibleFlow").Range("D14") =
Sheets("isothermal compressibleFlow").Range("S20")
   Sheets("isothermal compressibleFlow").Range("D15") =
Sheets("isothermal compressibleFlow").Range("S24")
   Sheets("isothermal compressibleFlow").Range("D16") =
Sheets("isothermal compressibleFlow").Range("S29")
   Sheets("isothermal compressibleFlow").Range("D19") =
Sheets("isothermal compressibleFlow").Range("S25")
   Sheets("isothermal compressibleFlow").Range("D17") =
Sheets("isothermal compressibleFlow").Range("S30")
   Sheets("isothermal compressibleFlow").Range("S11").GoalSeek Goal:=0,
ChangingCell:=Sheets("isothermal compressibleFlow").Range("S7")
   Sheets("isothermal compressibleFlow").Range("D18") =
Sheets("isothermal compressibleFlow").Range("S31")
   Sheets("isothermal compressibleFlow").Range("D12") =
Sheets("isothermal compressibleFlow").Range("S28")
   Sheets("isothermal compressibleFlow").Range("D4") =
Sheets("isothermal compressibleFlow").Range("Q17")
  End If
End Sub
```

REFERENCES

[1] T.K. Jack, "A Simplified Pipeline Calculations Program: Liquid Flow (1)", *International Journal of Scientific & Engineering Research*, submitted for publication. (Pending publication).

[2] C.L. Yaws, "Correlation constants for Chemical Compounds", *Chemical Engineering*, pp. 79-87, Aug. 16, 1976

[3] C.L. Yaws, "Correlation constants for Liquids", *Chemical Engineering*, pp.127-135, Oct.25, 1976

[4] C.L. Yaws, "Correlation constants for Chemical Compounds", *Chemical Engineering*, pp.153-162, Nov. 22, 1976

[5] C.L. Yaws, *Physical Properties*, McGraw Hill, 1977

[6] AlignaGraphics Co., Pipeline Sizing Program, *Pipedi User Manual*, 1998

[7] J.B. Evett, *2500 Solved Problems in Fluid Mechanics and Hydraulics*, McGraw-Hill, 1989

[8] A. Esposito, *Fluid Power with Applications*, Prentice Hall, 1980

[9] R.N. Fox, *Introduction to Fluid Mechanics*, Wiley, 1992.

[10] R.W. Miller, *Flow Measurement Engineering Handbook*, McGraw-Hill, 1985

[11] R.H. Perry, and D.W. Green, (eds), *Perry's Chemical Engineers' Handbook*, 6th edn., McGraw-Hill, 1984

[12] V.L. Streeter, *Fluid Mechanics*, McGraw-Hill, 1983

Biographical notes

T. K. Jack is a Registered Engineer, and ASME member. He worked on rotating equipment in the Chemical Fertilizer industry, and on gas turbines in the oil and gas industry. He has Bachelors degree in Mechanical Engineering from the University of Nigeria, and Masters Degrees in Engineering Management from the University of Port Harcourt, and in Rotating Machines Design from the Cranfield University in England. He was the Managing Engineer of a UK Engineering Software Company, ALIGNagraphics and the developer of a Pipeline sizing program, "*PipeDi*". He

is a consultant to the Seltrolene Co. and a University Teacher in Port Harcourt, Rivers State, Nigeria, teaching undergraduate classes in Mechanical Engineering. He can be reached by Email: - tonyekjack@yahoo.com