COMPRESSIBLE FLOW CALCULATOR

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Contents

Introduction

This document describes the basis and operation of the Blackmonk Engineering Compressible Flow Calculator.

The calculation methodology is based on that described in Crane Technical Paper 410M "The Flow of Fluids Through Valves, Fittings and Pipes" and Coulson & Richardson "Chemical Engineering Volume 1 Fluid Flow, Heat Transfer and Mass Transfer".

The calculator determines the pressure drop for compressible flow through a pipe given the required gas flow rate and details of the piping system.

The calculator determines the pressure drop based on isothermal flow and adiabatic flow of an ideal gas.

Calculation Inputs

The following parameters are user specified inputs to the calculation:

Line Details

Input	Description	Units
Line number	Optional user specified line number	N/A
Source	Optional user specified source of line	N/A
Destination	Optional user specified destination of line	N/A

Flow Type

Input	Description	Units
Type of flow	Mandatory user specified flow type: isothermal or adiabatic	N/A

Fluid Properties

Input	Description	Units
Fluid	Optional user specified name of fluid	N/A
Flowrate	Mandatory user specified flow rate	kg/hr
Inlet density	Mandatory user specified fluid density at pipe inlet	kg/m^3
Viscosity	Mandatory user specified fluid viscosity	cP
Inlet temperature	Mandatory user specified fluid temperature at pipe inlet	C
Inlet pressure	Mandatory user specified fluid pressure at pipe inlet	bara
Ratio of specific heat capacities	Mandatory user specified fluid ratio of specific	N/A

	heat capacities	

Pipelines

Input	Description	Units
Pipe NB	Mandatory user specified pipe nominal bore (nominal diameter)	inch
Pipe schedule	Mandatory user specified pipe schedules. Selected from a drop down list of valid values for the specified pipe nominal bore	N/A
Pipe length	Mandatory user specified pipe length	m
Absolute roughness	Mandatory user specified absolute roughness of the inside of the pipe	mm

Fittings

Input	Description	Units
90° LR bends	Mandatory user specified quantity of 90° long radius bends (can be zero)	N/A
90° Std elbows	Mandatory user specified quantity of 90° standard radius elbows (can be zero)	N/A
45° LR bends	Mandatory user specified quantity of 45° long radius bends (can be zero)	N/A
45° Std elbows	Mandatory user specified quantity of 45° standard radius elbows (can be zero)	N/A
Straight tees (flow thro' run)	Mandatory user specified quantity of straight tees with the fluid flow through the tee (can be zero)	N/A
Straight tees (flow thro' branch)	Mandatory user specified quantity of straight tees with the fluid flow through the branch of the tee (can be zero)	N/A
Pipe entrances	Mandatory user specified quantity of pipe entrances (can be zero)	N/A
Pipe exits	Mandatory user specified quantity of pipe exits (can be zero)	N/A
Pipe contractions	Mandatory user specified quantity of pipe contractions (can be zero)	N/A
Pipe expansions	Mandatory user specified quantity of pipe expansions (can be zero)	N/A
Gate valves	Mandatory user specified quantity of gate valves (can be zero)	N/A
Globe valves	Mandatory user specified quantity of globe valves (can be zero)	N/A
Swing check valves	Mandatory user specified quantity of swing check valves (can be zero)	N/A
Lift check valves	Mandatory user specified quantity of lift check valves (can be zero)	N/A
Tilting disc check valves	Mandatory user specified quantity of tilting check valves (can be zero)	N/A
Stop check valves	Mandatory user specified quantity of stop check valves (can be zero)	N/A
Poppet foot valves (with strainers)	Mandatory user specified quantity of poppet foot valves (can be zero)	N/A

Hinged disc foot valves (with strainers)	Mandatory user specified quantity of hinged disc foot valves with strainers (can be zero)	N/A
Ball valves	Mandatory user specified quantity of ball valves (can be zero)	N/A
Butterfly valves	Mandatory user specified quantity of butterfly valves (can be zero)	N/A
Plug valves	Mandatory user specified quantity of plug valves (can be zero)	N/A
Miscellaneous losses	Mandatory user specified quantity of miscellaneous velocity head losses (can be zero)	N/A
Fittings factor	Mandatory user specified design factor to be applied to the total number of fittings velocity head losses	N/A

Calculation Outputs

The following parameters are calculated by the software and displayed to the user:

Output	Description	Units
Pipe internal diameter	The pipe internal diameter determined from the selected pipe nominal diameter and schedule	mm
Relative roughness	Ratio of absolute pipe roughness to pipe internal diameter	N/A
Flow area	Cross sectional area of the inside of the pipe	m^2
Velocity	Fluid velocity through the pipe based on the flow area	m/s^2
Reynolds No.	Fluid Reynolds number based on the pipe internal diameter	N/A
Flow regime	Laminar, transition or turbulent based on the Reynolds number	N/A
Friction factor	Darcy friction factor	N/A
Pipe velocity head loss	Velocity head loss resistance coefficient for the pipe excluding fittings	N/A
Fittings total velocity head loss	Total velocity head loss resistance coefficient for the pipe fittings including the fittings factor	N/A

Output	Description	Units
Mach number	Fluid Mach number at the pipe inlet and outlet	N/A
Temperature	Fluid temperature at the pipe inlet and outlet	C
Density	Fluid density at the pipe inlet and outlet	kg/m^3
Volumetric flow rate	Fluid volumetric flow rate at the pipe inlet and outlet conditions	m^3/hr
Velocity	Fluid velocity at the pipe inlet and outlet	m/s
Pressure	Fluid pressure at the pipe inlet and outlet	bara
Critical velocity	Fluid critical velocity at the pipe inlet and outlet conditions	m/s
Choked flow?	If the calculated fluid velocity is greater or equal to the critical velocity, the flow is choked	N/A

Compressible Flow in a Pipe

Compressible flow of a gas or vapour usually needs to be considered when the density of the fluid changes significantly between the inlet and outlet of a pipe. In general the following guidelines can be used to determine if compressible flow should be considered:

1. If the calculated pressure drop between the pipe inlet and outlet is less than 10% of the inlet pressure, it is reasonable to use the Darcy formula for incompressible flow using the fluid density at either the pipe inlet or outlet.
2. If the calculated pressure drop between the pipe inlet and pipe outlet is between 10% and 40% of the inlet pressure, the Darcy formula for incompressible flow using a fluid density based on the average of the pipe inlet and outlet conditions will give reasonable accuracy.
3. If the pressure drop between the pipe inlet and outlet is greater than 40% then compressible flow should be considered.

Precise calculation of the pressure drop of a compressible fluid flowing through a pipe requires the relationship between pressure and density to be defined. In most cases, this relationship is not known. As a result, the extremes of the pressure and density relationships are usually used in the calculation of compressible flow. These extremes are adiabatic flow and isothermal flow.

Adiabatic flow is usually assumed in short, insulated pipes. Isothermal flow is usually assumed for long lines.

Isothermal Flow

Isothermal flow through a pipe is defined by the complete isothermal flow equation (Ref: Crane Technical Paper 410M, Page 1-8):

$$m = \left[\left[\frac{A^2 \rho_1}{K_{total} + 2\ln\left(\frac{P_1}{P_2}\right)} \right] \left[\frac{P_1^2 - P_2^2}{P_1} \right] \right]^{0.5}$$

Equation 1

Adiabatic Flow

Adiabatic flow through a pipe is defined by the following 2 equations (Ref: Coulson & Richardson Vol. 1, Page 140):

$$K_{total} = \left[\frac{\gamma-1}{2\gamma} + P_1\rho_1\left(\frac{A}{m}\right)^2\right]\left[1-\left(\frac{\rho_2}{\rho_1}\right)^2\right] - \frac{\gamma+1}{\gamma}\ln\left(\frac{\rho_1}{\rho_2}\right)$$ **Equation 2**

$$\frac{1}{2}\left(\frac{m}{A}\right)^2\left(\frac{1}{\rho_1}\right)^2 + \frac{\gamma}{\gamma-1}\left(\frac{P_1}{\rho_1}\right) = \frac{1}{2}\left(\frac{m}{A}\right)^2\left(\frac{1}{\rho_2}\right)^2 + \frac{\gamma}{\gamma-1}\left(\frac{P_2}{\rho_2}\right)$$ **Equation 3**

Frictional Head Loss

The total friction head loss in a system is the sum of the frictional head loss in the pipe and the frictional head loss in the fittings.

$$H_{friction\_head\_total} = H_{friction\_head\_pipe} + H_{friction\_head\_fittings}$$ **Equation 4**

Frictional head loss through a pipe is calculated using the Darcy-Weisbach formula (Ref: Crane Technical Paper 410M, Page 1-6):

$$H_{friction\_head\_pipe} = f\frac{L}{d}\frac{u^2}{2g}$$ **Equation 5**

This relationship can also be expressed in terms of velocity head loss resistance coefficient:

$$H_{friction\_head\_pipe} = K_{pipe}\frac{u^2}{2g}$$ **Equation 6**

Where

$$K_{pipe} = f\frac{L}{d}$$ **Equation 7**

Pipe Friction Factor

For laminar flow (Re<2000) the friction factor is given by (Ref: Crane Technical Paper 410M):

$$f = \frac{64}{\mathrm{Re}}$$ **Equation 8**

For turbulent flow (Re>4000) the friction factor is calculated using the Churchill equation (Ref: Perry's 7th Ed, Page 6-11):

$$f = 4\left[-4\log\left[\frac{0.27\varepsilon}{d} + \left(\frac{7}{\mathrm{Re}}\right)^{0.9}\right]\right]^{-2}$$ **Equation 9**

In the transition zone between 2000 < Re < 4000 the friction factor is indeterminate and has lower limits based on laminar flow conditions and upper limits based on turbulent flow conditions. To produce a conservative value for the calculated friction factor, the turbulent flow friction factor equation is used throughout the transition zone in this calculation.

Fittings Frictional Head Loss

Frictional head loss through pipe fittings is calculated using the "resistance coefficient" version of the Darcy-Weisbach equation (Ref: Crane Technical Paper 410M, Page 2-8):

$$H_{friction\_head\_fittings} = K_{fittings}\frac{u^2}{2g}$$ **Equation 10**

The resistance coefficient of the various pipe fittings used in the calculator are based on data from Crane Technical Paper 410M. In general the resistance coefficient for each type of fitting is dependent on the nominal size of the pipe fitting.

In these cases, the resistance coefficient for each type and size of fitting is calculated from the following equation:

$$K_{fitting} = C \times f_T$$ **Equation 11**

Where C is a constant representing the equivalent length:diameter of the particular fitting and f_T is the friction factor for the appropriate size of the fitting.

Table 1: Fitting Friction Factors

Nominal Pipe Size (in)	Fitting Friction Factor f_T
0.125	0.036
0.25	0.031
0.375	0.028
0.5	0.027
0.75	0.025
1	0.023
1.25	0.022
1.5	0.021
2	0.019
2.5	0.018
3	0.018

4	0.017
5	0.016
6	0.015
8	0.014
10	0.014
12	0.013
14	0.013
16	0.013
18	0.012
20	0.012
22	0.012
24	0.012

Table 2: Equivalent Length:Diameter Constants for Various Fittings

Fitting	C	K
90° LR bends	14	-
90° Std elbows	30	-
45° LR bends	10	-
45° Std elbows	16	-
Straight tees (flow thro' run)	20	-
Straight tees (flow thro' branch)	60	-
Pipe entrances	-	0.5
Pipe exits	-	1
Pipe contractions	-	0.5
Pipe expansions	-	1
Gate valves	8	-
Globe valves	340	-
Swing check valves	50	-
Lift check valves	600	-
Tilting disc check valves	40	-
Stop check valves	400	-
Poppet foot valves (with strainers)	420	-
Hinged disc foot valves (with strainers)	75	-
Ball valves	3	-
Butterfly valves	45	-
Plug valves	18	-

Total Frictional Head Loss

The total frictional head loss of the pipe and fittings combined is given by the following equation:

$$K_{total} = K_{pipe} + K_{fittings}$$ **Equation 12**

Calculation of Fluid Velocity

Fluid velocity is calculated using the user specified mass flow rate, the fluid density and the internal pipe diameter defined by the selected nominal pipe size and schedule.

The flow area is given by:

$$A = \frac{\pi d^2}{4} \qquad \textbf{Equation 13}$$

The volumetric flow rate is determined using:

$$Q = \frac{m}{\rho} \qquad \textbf{Equation 14}$$

The fluid velocity is then determined by:

$$u = \frac{Q}{A} \qquad \textbf{Equation 15}$$

Pipe Relative Roughness

The pipe relative roughness is the ratio of the absolute roughness of the inside of the pipe to the pipe inside diameter.

$$\text{Relative roughness} = \frac{\varepsilon}{d} \qquad \textbf{Equation 16}$$

Reynolds Number

Reynolds number is determined using the relationship:

$$\mathrm{Re} = \frac{\rho u d}{\mu} \qquad \textbf{Equation 17}$$

Flow Regime

The calculator classifies the flow regime as laminar, transition or turbulent based on the Reynolds number.

Table 3: Flow Regime Classification

Reynolds Number	Flow Regime
Re < 2000	Laminar
2000 < Re < 4000	Transition
Re > 4000	Turbulent

Calculation of Critical Velocity

The critical velocity of a compressible fluid is the maximum possible velocity of the fluid in a pipe. The critical velocity is equivalent to the speed of sound in the fluid and is also referred to as sonic velocity. If the pressure drop through a pipe is sufficiently large, the density of the fluid will decrease and the fluid velocity will increase until it reaches the critical velocity. Once the critical velocity has been reached, any further reduction in pressure will not result in an increase in fluid velocity within the pipe.

The critical velocity of a compressible fluid is given by:

$$u_{critical} = \sqrt{\frac{\gamma P}{\rho}}$$ **Equation 18**

The flow is choked if:

$$u \geq u_{critical}$$ **Equation 19**

Mach Number

The Mach number is determined using the following relationship:

$$M = u\sqrt{\frac{\rho}{\gamma P}}$$ **Equation 20**

Isothermal Fluid Outlet Density

The fluid outlet density for isothermal flow is calculated using the following equation:

$$\rho_2 = \rho_1 \frac{P_2}{P_1}\frac{T_1}{T_2}$$ **Equation 21**

Adiabatic Fluid Outlet Temperature

The fluid outlet temperature for adiabatic flow is calculated using the following equation:

$$T_2 = T_1 \frac{P_2}{P_1} \frac{\rho_1}{\rho_2}$$ **Equation 22**

Pressure Drop Through Pipe

The pressure drop through the pipe is calculated using the following equation:

$$\Delta P = P_1 - P_2$$ **Equation 23**

Calculation of Compressible Pressure Drop

The compressible pressure drop is determined from the specified fluid properties, inlet conditions, selected flow type, pipe details and fittings details.

The calculation routine is described in the following steps:

1. Calculate pipe relative roughness using Equation 16
2. Calculate flow area using Equation 13
3. Calculate Reynolds number using Equation 17
4. Determine flow regime using Table 3
5. Calculate pipe friction factor using Equation 8 for laminar flow and Equation 9 for transition and turbulent flow
6. Calculate pipe velocity head loss using Equation 7
7. Calculate fittings velocity head loss using Equation 11, Table 1 and Table 2 for each fitting
8. Calculate total velocity head loss for the pipe and fittings using Equation 12
9. Calculate inlet volumetric flow rate using Equation 14
10. Calculate inlet velocity using Equation 15
11. Calculate inlet Mach number using Equation 20
12. Calculate inlet critical velocity using Equation 18
13. Determine if inlet flow is choked using Equation 19
14. For isothermal flow, calculate outlet pressure by solving Equation 1 iteratively
15. For isothermal flow, calculate the outlet density using Equation 21
16. For adiabatic flow, calculate the outlet density by solving Equation 2 iteratively
17. For adiabatic flow, calculate the outlet pressure using Equation 3
18. For adiabatic flow, calculate the outlet temperature using Equation 22
19. Calculate outlet volumetric flow rate using Equation 14
20. Calculate outlet velocity using Equation 15
21. Calculate outlet Mach number using Equation 20

22. Calculate outlet critical velocity using Equation 18
23. Determine if outlet flow is choked using Equation 19
24. Calculate pressure drop through the pipe using Equation 23

If the specified flow rate is too large to be achieved with the available pressure drop, the calculation reports an error.

The calculator solves the equations for isothermal and adiabatic flow numerically using the Secant Method of iteration.

Nomenclature

$H_{friction\_head\_pipe}$ = Frictional head loss through pipe (m)
$H_{friction\_head\_fittings}$ = Frictional head loss through fittings (m)
$H_{friction\_head\_total}$ = Total frictional head loss through pipe and fittings (m)
ρ = Density of fluid (kg.m^{-3})
μ = Viscosity of fluid (Pa.s)
γ = Ratio of specific heat capacities of fluid (dimensionless)
g = Acceleration due to gravity (m.s^{-2})
f = Darcy friction factor (dimensionless)
f_T = Fitting friction factor (dimensionless)
L = Length of pipe (m)
d = Inside diameter of pipe (m)
u = Fluid velocity (m.s^{-1})
$u_{critical}$ = Fluid critical velocity (m.s^{-1})
Re = Reynolds number (dimensionless)
ε = Absolute roughness of pipe inside wall (m)
K_{pipe} = Resistance coefficient of pipe (dimensionless)
$K_{fittings}$ = Resistance coefficient of pipe fittings (dimensionless)
$K_{fitting}$ = Resistance coefficient of a particular pipe fitting (dimensionless)
K_{total} = Total resistance coefficient of pipe and pipe fittings (dimensionless)
C = Equivalent length : diameter coefficient of a particular pipe fitting
A = Flow area (m^2)
Q = Volumetric flow rate through pipe (m^3.s^{-1})
m = Mass flow rate through pipe (kg.s^{-1})
P = Fluid pressure (Pa abs)
P_1 = Upstream pressure (Pa abs)
P_2 = Downpstream pressure (Pa abs)
ΔP = Pressure drop through pipe (Pa)
T = Fluid temperature (K)
T_1 = Upstream temperature (K)
T_2 = Downstream temperature (K)
ρ_1 = Density of fluid at upstream conditions (kg.m^{-3})
ρ_2 = Density of fluid at downstream conditions (kg.m^{-3})
M = Mach number (dimensionless)

Example 1 – Isothermal Flow

The following example was adapted from Crane Technical Paper 410M "Flow of Fluids Through Valves, Fittings and Pipes" Example 4-18.

Description:

Natural gas is transported through a pipeline, 14" nominal bore, wall thickness 11 mm, inside diameter 333.6 mm, 160 km long. The inlet pressure is 90 bara and the average temperature is 4C. The flow rate of natural gas is 2.938 million m^3/day measured at 15C, 1 atm.

Fluid molecular weight = 20.1
Fluid viscosity = 0.011 cP
Fluid ratio of specific heats = 1.32 (assumed value for natural gas)

Requirement:

Find the outlet pressure of the pipeline.

Solution:

Natural gas density at 15C, 1 atm =

$$(101325 \times 20.1) / (8314 \times (273+15)) = 0.851 \text{ kg/m}^3$$

Natural gas mass flow rate =

$$2.938 \times 10^6 \times 0.851 = 2500238 \text{ kg/day} = 104177 \text{ kg/hr}$$

Fluid density at inlet conditions, 90 bara, 4C =

$$(90 \times 10^5 \times 20.1) / (8314 \times (273+4)) = 78.55 \text{ kg/m}^3$$

Assumed pipe roughness = 0.043 to generate a friction factor of 0.0128 consistent with the friction factor assumed in the Crane example.

Calculated outlet pressure = 20.05 bara (cf: 20 bara published in Crane)

Compressible Flow Calculator Screenshot Example 1:

LINE DETAILS

Line number	P-001
Source	V-001
Destination	V-002

FLOW TYPE

Type of flow	Isothermal

FLUID PROPERTIES

Fluid		Natural Gas	
Flowrate	m	104177	kg/hr
Inlet density	ρ_{in}	78.55	kg/m3
Viscosity	μ	0.011	cP
Inlet temperature	T_1	4	C
Inlet pressure	P_1	90.00	bara
Ratio of specific heat capacities	γ	1.32	

PIPELINE

Pipe nominal diameter		14	inch
Pipe schedule		N/A	
Pipe internal diameter	d	333.6	mm
Pipe length	l	160000	m
Absolute roughness	e	0.043	mm

FITTINGS

Quantities	
90° LR bends	0
90° Std elbows	0
45° LR bends	0
45° Std elbows	0
Straight tees (flow thro' run)	0

Straight tees (flow thro' branch)	0
Pipe entrances	0
Pipe exits	0
Pipe contractions	0
Pipe expansions	0
Gate valves	0
Globe valves	0
Swing check valves	0
Lift check valves	0
Tilting disc check valves	0
Stop check valves	0
Poppet foot valves (with strainers)	0
Hinged disc foot valves (with strainers)	0
Ball valves	0
Butterfly valves	0
Plug valves	0

Miscellaneous losses (no. velocity heads)	0

Fittings factor	1

OUTPUTS

Relative roughness	e:d	0.00013	
Flow area	A	0.08741	m2
Reynolds No.	Re	10040625	
Flow regime		turbulent	
Friction factor	f	0.01277	
Pipe velocity head loss	K_{pipe}	6126.671	
Fittings total velocity head loss	$K_{fittings}$	0.000	

		Inlet	Outlet	
Mach number	Mach	0.0108	0.0487	
Temperature	T	4.0	4.0	C
Density	ρ	78.5500	17.4950	kg/m3
Volumetric flow rate	Q	0.3684	1.6541	m3/s
Velocity	u	4.21	18.92	m/s
Pressure	P	9000000.0	2004525.1	Pa abs
Critical velocity	$u_{critical}$	388.90	388.90	m/s

Choked flow?		NO	NO		
Isothermal flow equation		837.41106	837.41111	Check	-5.1577E-05
Isothermal outlet pressure			2004525.1		
Adiabatic flow outlet density			1.2872	kg/m3	
Adiabatic density equation		6126.671	6440.870469	Check	314.199802
Adiabatic outlet pressure			137168.2089	Pa abs	
Outlet pressure	P_2	**20.05**	**bara**		
Pressure drop through pipe	ΔP	**69.95**	**bar**		

Example 2 – Adiabatic Flow

The following example was adapted from Crane Technical Paper 410M "Flow of Fluids Through Valves, Fittings and Pipes" Example 4-22.

Description:

Air at a pressure of 1.33 barg and 40C is measured at a point 3 metres from the outlet of a ½ inch Schedule 80 pipe discharging to atmosphere.

Pipe length = 3m
Pipe fittings: 1 pipe exit
Fluid molecular weight = 29
Fluid viscosity = 0.018 cP
Fluid ratio of specific heats = 1.40 (assumed value for air)

Requirement:

Find the flow rate of air discharging to atmosphere.

Solution:

Air density at 40C, 1.33 barg =

$$(2.34 \times 10^5 \times 29) / (8314 \times (273+40)) = 2.61 \text{ kg/m}^3$$

Assumed pipe roughness = 0.044 to generate a friction factor of 0.0275 consistent with the friction factor assumed in the Crane example.

The input flow rate was varied until the calculator determined an outlet pressure of 1.01 bara (atmospheric pressure)

Calculated flow rate = 131.5 kg/hr (cf: 129.6 kg/hr published in Crane)

Note:

Crane published flow rate = 1.76 m^3/min at 15C, 1 atm.

Density of air at 15C, 1 atm =

$$(101325 \times 29) / (8314 \times (273+15)) = 1.227 \text{ kg/m}^3$$

Mass flow rate = 1.76 x 60 x 1.227 = 129.6 kg/hr

Compressible Flow Calculator Screenshot Example 2:

LINE DETAILS

Line number	P-001
Source	V-001
Destination	V-002

FLOW TYPE

Type of flow	Adiabatic

FLUID PROPERTIES

Fluid		Air	
Flowrate	m	131.5	kg/hr
Inlet density	ρ_{in}	2.61	kg/m3
Viscosity	μ	0.018	cP
Inlet temperature	T_1	40	C
Inlet pressure	P_1	2.34	bara
Ratio of specific heat capacities	γ	1.4	

PIPELINE

Pipe nominal diameter		0.5	inch
Pipe schedule		Sch 80	
Pipe internal diameter	d	13.8	mm
Pipe length	l	3	m
Absolute roughness	e	0.044	mm

FITTINGS

Quantities	
90° LR bends	0
90° Std elbows	0
45° LR bends	0
45° Std elbows	0
Straight tees (flow thro' run)	0

Straight tees (flow thro' branch)	0
Pipe entrances	0
Pipe exits	1
Pipe contractions	0
Pipe expansions	0
Gate valves	0
Globe valves	0
Swing check valves	0
Lift check valves	0
Tilting disc check valves	0
Stop check valves	0
Poppet foot valves (with strainers)	0
Hinged disc foot valves (with strainers)	0
Ball valves	0
Butterfly valves	0
Plug valves	0

Miscellaneous losses (no. velocity heads)	0

Fittings factor	1

OUTPUTS

Relative roughness	e:d	0.00319	
Flow area	A	0.00015	m2
Reynolds No.	Re	187233	
Flow regime		turbulent	
Friction factor	f	0.02749	
Pipe velocity head loss	K_{pipe}	5.976	
Fittings total velocity head loss	$K_{fittings}$	1.000	

		Inlet	Outlet	
Mach number	Mach	0.2641	0.5927	
Temperature	T	40.0	23.5	C
Density	ρ	2.6100	1.1948	kg/m3
Volumetric flow rate	Q	0.0140	0.0306	m3/s
Velocity	u	93.57	204.39	m/s
Pressure	P	234000.0	101487.6	Pa abs
Critical velocity	$u_{critical}$	354.28	344.84	m/s

Choked flow?		NO	NO		
Isothermal flow equation		0.00133	-0.34853	Check	0.349868575
Isothermal outlet pressure			1963663.1		
Adiabatic flow outlet density			1.1948	kg/m3	
Adiabatic density equation		6.976	6.975942109	Check	0.000016
Adiabatic outlet pressure			101487.5706	Pa abs	
Outlet pressure	**P_2**	**1.01**	**bara**		
Pressure drop through pipe	**ΔP**	**1.33**	**bar**		