

For flow of an incompressible Newtonian liquid in a pipe the friction loss is calculated according to the Darcy-Weisbach equation:

$$\Delta P_{\text{fric}} = 0.5f_D L \rho v^2 / D$$

For flow of a **compressible fluid (gas or vapour)** in a pipe the Darcy-Weisbach equation is not applicable because both density and velocity change as the fluid flows down the pipe. For gas flow friction loss is never equal to total loss, because velocities and densities in and out of the pipe are always different. An approach often used in the literature is to assume ideal gas laws so that analytical equations can be derived. In many industrial processes significant departures from the ideal gas laws exist.

Rather than make simplifying assumptions, *FluidFlow3* uses a calculation procedure that solves the conservation equations together with an equation of state for small pipe increments. This means that we cannot provide an analytical expression for pipe friction loss. To help understand the solution process consider the following description:

1. A pipe increment is selected based on a small change in fluid static density ρ_1 and ρ_2 . The length of this increment is not yet known.

2. The following upstream properties are calculated:

$$\text{Velocity, } v_1 = G / \rho_1$$

$$\text{Static temperature, } T_1 = T^0 - 0.5v_1^2 / C_{p1}$$

$$\text{Static pressure } P_1 = P^0 - 0.5\rho_1 v_1^2$$

Upstream stagnation enthalpy is obtained from the equation of state, knowing the upstream stagnation temperature, T^0 and pressure P^0 .

3. Downstream stagnation enthalpy is calculated (any heat transfer is included at this stage). From the downstream stagnation enthalpy the downstream static temperature, T_2 is calculated.

4. From the downstream static temperature, T_2 and density, ρ_2 the equation of state is back solved to provide the downstream static pressure, P_2 . FluidFlow can use either Peng Robinson; Benedict Webb Rubin; or Lee Kesler equations of state.

5. An incremental form of the energy equation is used to calculate the length of this pipe segment;

$$\Delta L_{\text{segment}} = (p_1 - p_2 - 2D\rho_{\text{av}}G^2 / (1/\rho_1 - 1/\rho_2)) / (f_D G^2)$$

6. Steps 1 to 5 are repeated until the end of the pipe is reached. The incremental length step size therefore shortens as the calculation moves down the pipe. For the last segment, which will never be the exact length required, we use interpolating functions based on results from previous segments.

This basis of this method was originally developed for calculating high speed gas flows in pressure relief lines.

For more details refer to the help files.

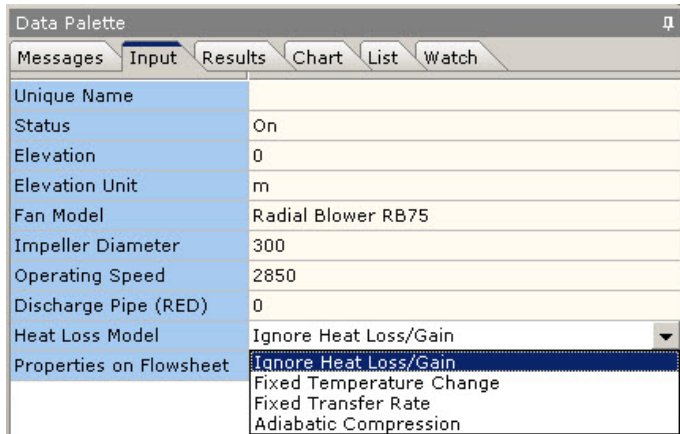
TEMPERATURE CHANGE ACROSS FANS

Temperature change for fans is accommodated via the Input Inspector. Heat Loss Model: For a fan or compressor there are 4 possible entries: Ignore Heat Loss/Gain; Fixed Temperature Change; Fixed Transfer Rate; Adiabatic Compression. Selecting Ignore Heat Loss/Gain means that flow across the element is ignored. Selecting Fixed Temperature Change allows you to specify a temperature change for the fluid as it flows through the fan. Fixed Transfer Rate allows you to specify a fixed amount of heat to be either taken out of or added to the fluid as it flows through the fan. Selecting Adiabatic Compression means that FluidFlow will estimate the temperature rise due to adiabatic compression.

If Adiabatic compression is selected as the heat loss model then FluidFlow estimates the output temperature from the expression

$$T_2 = T_1 + (P_2/P_1)^n$$

where pressures and temperatures refer to static conditions and n is the Cp/Cv ratio



GAS FLOW COMPARISON

Results for *FluidFlow3* compared to three other software packages are given overpage. Pipenet is a generic pipe network analysis program; GasWorks is primarily for the design of natural gas reticulation and distribution systems, AFT Arrow is a highly sophisticated compressible flow program.

CALCULATION OF METHANE FLOW THROUGH A LONG PIPELINE

Pipe Type: Sch 40 Steel
 Pipe Length: 46km
 Fluid: Methane
 Temperature: 15 deg C
 Upstream pressure: 10,000 kPa g
 Downstream pressure: 2,000 kPa g

PIPE SIZE (nominal inches)	FLOWRATE (STD M ³ /HR)					
	FLUIDFLOW3	ARROW*	PIPENET	GASCALC		
				Darcy-Weisbach	AGA Full Eff=100%	Panhandle A Eff=90%
12	233320	222082	224390	233450	218372	267365
10	147821	144133	146010	147943	138605	n/a
8	81732	82412	83135	81781	76654	n/a
6	39996	40288	40980	40012	37527	n/a
4	13721	13065	13780	13721	12884	n/a
2	2390	2276	2395	2389	2249	n/a

*Note – each Arrow reports choked conditions at the outlet for each pipe. None of the other programs reports this.

Equations:

FluidFlow3: See above.
 Pipenet: Van de Waals gas assumed.
 GasWorks: As shown in the table.
 AFT Arrow: Length march with mach number limits.

Software:

FluidFlow3 Version 3.20.1
 Pipenet: Version 3.11
 GasCalc: Version 4.0
 AFT Arrow: Version 4.0

COMPARISON WITH CRANE EXAMPLE 4-16 *

Design Objective: To determine the pressure drop in a 25m, 1" pipe and the velocities at the upstream and downstream ends. Discharge – 3.0 Sm³/min of air at 40 deg C.

	PRESSURE DROP	UPSTREAM VELOCITY	DOWNSTREAM VELOCITY
	(bar)	(m/s)	(m/s)
FLUIDFLOW3	0.209	16.39	17.02
CRANE	0.205	16.45	17.05
AFT ARROW	0.211	16.47	17.07

**Flow of Fluids Through Valves, Fitting and. Pipes (Crane Publication 410M)*

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