PIPESIZE spreadsheet template for pipe sizing.

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PIPESIZE is an Excel spreadsheet template. It sizes pipes for liquid or gas flow. *PIPESIZE* is extensively tested; I created the first version in 1989 and have continually enhanced it since.

The 2013 version (3.10) adds a much improved calculation algorithm for heat loss/gain estimates, and a new Line List feature.

The template consists of several worksheets. Most of your data input is on the Data Input worksheet; the others are used for assembling reports and supporting data. Cells requiring User Input are displayed with RED text; other cells are in BLACK.

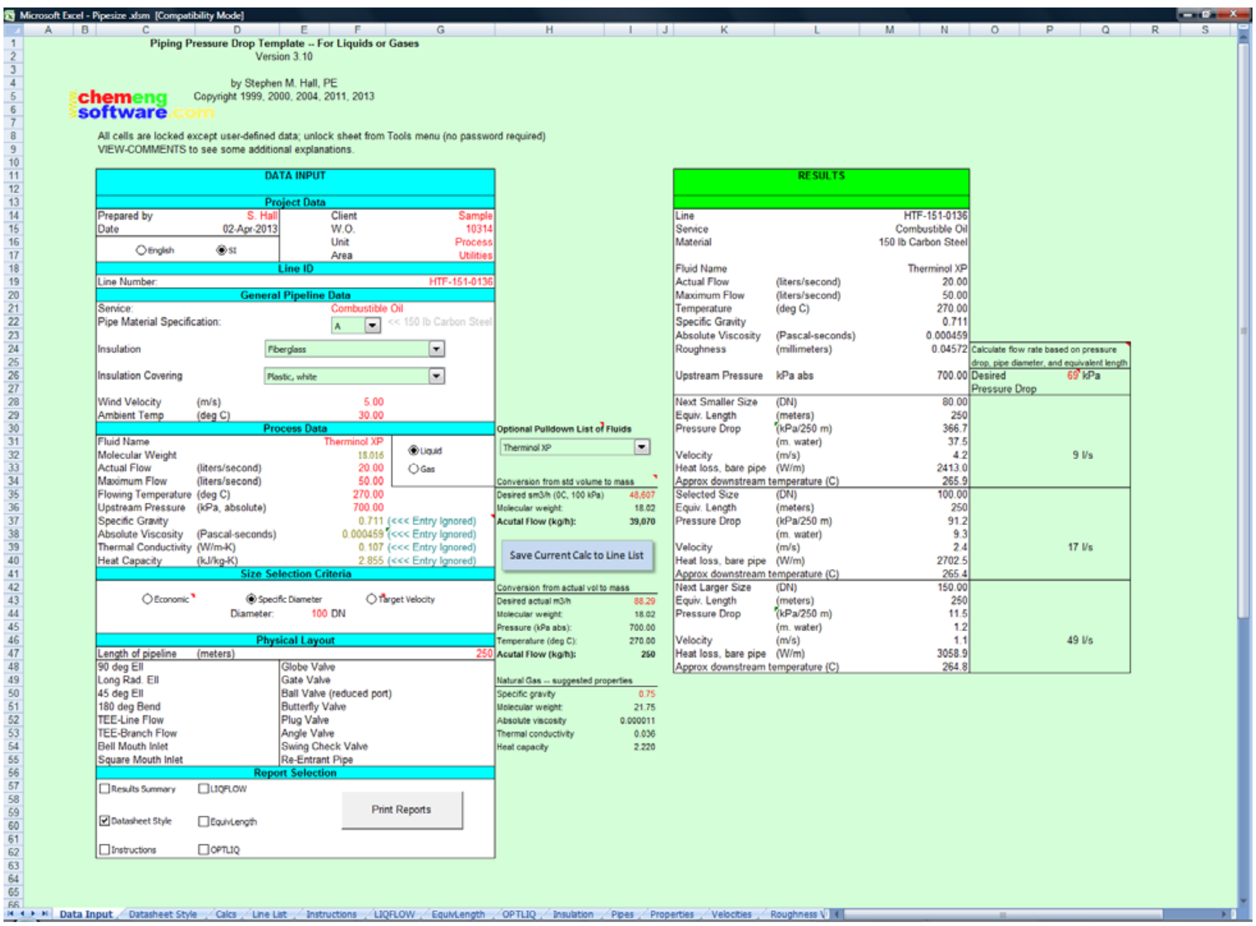

Figure 1: Most data input is done on the Data Input worksheet

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Quick Start

Perform your first pressure drop calculation by following these steps:

1. Ensure that Macros are enabled
2. Navigate to the Data Input worksheet
3. Cell C17: Choose preferred system of units, English or SI (radio buttons)
4. Cell G32: Choose Liquid or Gas (radio buttons)
5. Cell F31: Enter name of the fluid, or choose one from the pulldown list at H31
6. Cell F33: Enter the flowrate (be sure to use the units that are indicated)
7. Cell F36: If this is a gas calculation, enter the pressure
8. Take note of the messages at Cells E32, G37, G38, and G39. Enter data if it says “Entry Required” (it means that the fluid name entered in Cell 31 is missing from the Properties Table, see page 24)
9. Cell D43: If you are calculating for a known pipe diameter, select the “Specific Diameter” (radio button). Otherwise, select “Economic”
10. Cell G47: Enter the approximate equivalent length of the pipe segment you are calculating. If you don’t know the equivalent length, enter a value that is 1.4 times the actual length of the pipe.

Read results in the table in columns K:N. Notice that results for three pipe sizes are displayed. The specified size (or size determined by *PIPESIZE*) is in the middle, at Rows 35 to 41. It is flanked by the next smaller and next larger sizes.

There are many additional variables that you can enter; they are explained in this manual. However, for the most part, the inputs are self-explanatory.

System Requirements

- Personal computer running Microsoft Excel with Visual Basic for Applications (VBA). This requirement means that Open Office and other programs capable of opening and editing basic Excel worksheets will not work – VBA is required. Excel 97 on the Mac lacks VBA and is therefore incompatible, however Office 2010 on the Mac is compatible
- Excel must be configured to allow macros to run. This can be done through Security settings, or by enabling macros each time *PIPESIZE* is opened

Initial Setup and Orientation

When you first open *PIPESIZE* you should see the Data Input screen. If not, select the leftmost tab at the bottom of the Excel window.

We recommend that you start by exploring a bit. Entries that appear in RED are valid cells for data entry. The BLACK cells contain results from intermediate or final calculations. Generally, only the RED cells are unlocked. You quickly navigate among them by using the TAB key.

Although the worksheets are Protected, this is only done to help avoid inadvertent changes to cells that contain formulas. There are no passwords and the entire workbook is Open Source.

PIPESIZE is shipped configured for printing on US letter size paper. If you use A4 paper, please go to each sheet in turn. Go to Page Setup... Then change paper to A4 and left/right margins to 1.5 cm. The pages should then print properly.

Number and date formats vary around the world. While numeric values are formatted according to global settings in Excel, *PIPESIZE* also makes use of text formulas that are formatted according to a string within the formula. This string is unaffected by Excel's global formatting preferences, having a syntax such as: =TEXT(numeric value, "0.00"). To get around this problem, a table of formats is provided on the Pipes worksheet at Row 166. If you use anything other than "dd-mmm-yyyy" for dates, or "#,##0.0" for numbers, edit the formats in the table.

The next thing to do is review the Pipes worksheet. If your company or workgroup has standard pipe specifications you may want to edit the Pipes sheet to accurately portray your specs. If you don't have specifications, consider creating codes for commonly used types, such as "CS" (for carbon steel) and "SS" (stainless steel).

The pipe specification codes are entered in the table at the top of the Pipes worksheet. Codes must be entered in alphabetical order (you can insert new rows if you like). Then, follow the column headings to enter temperature and pressure limits, roughness value, cost data, and related dimensional table number. Although the entries in this table are in customary US units, the *PIPESIZE* reports use either US or SI units for reporting (in accordance with your selection). Each column entry is explained below.

						Cost Factors					
Spec Code	Description	Min Temp deg F	Max Temp deg F	Max Press psig	Roughness ft	Purchase $/ft (1 inch)	Ratio Fittings	Exponent	Size Table	Emissivity	Conductivity W/m-K
A	150 lb Carbon Steel	-10	450	150	0.00015	$1.75	5	1.3	2	0.79	45
A3	125 lb Carbon Steel	-10	450	125	0.00015	$1.75	5	1.3	2	0.79	54
B	300 lb Carbon Steel	-20	750	300	0.00015	$1.75	5	1.3	2	0.79	54
C	316L SS Pipe	-100	500	145	0.0001	$4.50	8	0.89	8	0.85	16.2
CU	Copper Pipe	-100	250	110	0.000005	$4.50	8	0.89	6	0.78	401
D1	316L SS Sanitary Tubir	-100	450	150	0.000001	$4.50	8	0.89	15	0.1	16.2
D2	316L SS Zephyrweld Tu	-100	450	150	0.000005	$4.50	8	0.89	14	0.1	16.2
F1	Teflon-Lined Pipe	-20	500	170	0.000005	$4.50	8	0.89	9	0.79	0.3

Figure 2: Pipe Specifications on the Pipes worksheet

Spec Code may be any alphanumeric string. It is usually a designation used on P&IDs and other documents that references a complete pipe specification. The Spec Codes must be sorted alphabetically. Rows may be inserted into the table if more codes are needed.

Description is plain language to describe the pipe specification. It is used on the printed data sheet.

Temperature limits are entered in degrees Fahrenheit. These are the minimum and maximum temperatures allowed for the pipe class, often determined by components in your piping system such as gaskets and valves. If the fluid temperature is outside the range defined by these limits a warning message is printed on the data sheet.

Pressure limit is the maximum gage pressure permitted (psig) for the pipe code. The only thing that temperature and pressure limits affects within *PIPESIZE* is a Warning in the event that the limits are violated.

Pipe Roughness is entered in units of feet. See the Roughness worksheet for a list of recommendations. Roughness for new pipe is often listed in handbooks, but consider whether it's more appropriate to use a value for used pipe -- one that is more representative of how your system will operate after a couple of years of operation.

Cost Factors are entered for a) initial capital cost of 1 foot of 1 inch pipe, installed, b) a ratio relating the cost of fittings and valves to the cost of pipe, and c) an exponent used to convert to other sizes. This is in accordance with the Peters and Timmerhaus method. We suggest you use values like the ones given until you gain experience with the OPTSIZE worksheet results.

Size Table is a pointer to one of the many pipe dimension tables appearing below. Each dimension table contains five columns of data, which in turn can be formulas to look up wall thicknesses for a given schedule, etc. Use the Pipe Specification Lookup Tables at Row 44 to control the minimum and maximum allowed diameters in your pipe specifications. Also use them to eliminate unwanted sizes such as 1-1/4" or 5". Study the tables given with *PIPESIZE*, and either edit an existing one or create new tables in columns to the right of the existing ones.

Size Table — Black values are formulas or constants — Red values are variables — Column name is user-defined

8					9					10		
Stainless Steel Pipe					Teflon-Lined Steel					Stainless Steel Tubing (		
Size	Schedule	O.D.	Thickness	I.D.	Size	Schedule	O.D.	Thickness	I.D.	Size	Gauge	O.D.
0.125	40S	0.405	0.0680	0.269	0.50	40	0.840	0.1630	0.514	0.75	16	0.750
0.25	40S	0.540	0.0880	0.364	0.75	40	1.050	0.1750	0.700	1.00	16	1.000
0.375	40S	0.675	0.0910	0.493	1.00	40	1.315	0.2630	0.789	1.50	16	1.500
0.50	40S	0.840	0.1090	0.622	1.50	40	1.900	0.2950	1.310	2.00	16	2.000
0.75	40S	1.050	0.1130	0.824	2.00	40	2.375	0.3140	1.747	2.50	16	2.500

The Pipe Specification Lookup Tables can reference any of the several dimension tables found in the PIPES worksheet. Study the Pipe Table formulas to see how this is done. Here's an example dimension table, used to lookup the dimensions of copper pipe:

Pipe Size Lookup Table					
Copper and Red Brass Pipe				Wall Thickness	
		Nominal Size	OD	Std	XS
		0.125	0.405	0.062	0.100
		0.25	0.540	0.082	0.123
		0.375	0.675	0.090	0.127
		0.50	0.840	0.107	0.149
		0.75	1.050	0.114	0.157

Emissivity is the radiation constant for a bare pipe. Suggested values are given in a table beginning at Row 138 on the Pipes worksheet; emissivity must be between 0 and 1.

Conductivity is the thermal conductivity of the pipe material, W/m-K. The heat loss/gain calculation does not include a provision for lined pipe, so use an estimate for combined conductivity, which should be greater than the material (usually the lining) with the smaller value. For example, the conductivity of polypropylene is 0.2 W/m-K. For polypropylene-lined pipe, where the thickness of the lining is greater than the thickness of the steel, use a value of 0.3 or 0.4 as an estimate for the combined lined pipe system.

Data Entry Worksheet

The data entry worksheet consists of several parts, discussed in turn below. Remember that RED cells are unlocked and available for entry. If you need to change the value of a locked cell, unprotect the worksheet from the Tools menu. There is no password. Use the TAB key to quickly navigate from one entry field to the next.

Project Data appears on the headers of each of the standard reports. Notice that the Date field is automatically filled with today's date. This can be changed by unprotecting the worksheet, as mentioned above. The formula in the date field is: =TEXT(TODAY(),"dd-mmm-yyyy")

The Units radio buttons control whether input and output are shown in English (*i.e.,* customary US) or SI units.

DATA INPUT			
Project Data			
Prepared by	S. Hall	Client	Sample
Date	02-Apr-2013	W.O.	10314
○ English	◉ SI	Unit	Process
		Area	Utilities
Line ID			
Line Number:			HTF-151-0136

General Pipeline Data refers to the piping system and materials. Service is a descriptive tag for the purpose of the pipeline. Any text is accepted. The pulldown box (contains "A" in the screen shot below) shows all of the pipe codes contained in the PIPES worksheet. The description of the selected code appears to the right. Similarly, the Insulation pulldown box permits you to select the insulation material for the pipe (or "None"). Heat loss calculations require input of wind velocity and ambient temperature, which are entered next.

General Pipeline Data			
Service:		Combustible Oil	
Pipe Material Specification:		A ▼	<< 150 lb Carbon Steel
Insulation		Fiberglass ▼	
Insulation Covering		Plastic, white ▼	
Wind Velocity	(m/s)	5.00	
Ambient Temp	(deg C)	30.00	

Process Data is entered next. Use the radio buttons to specify if you are sizing a line for gas flow or liquid. The units displayed next to each other entry will change depending on whether English or SI units are selected, and whether the fluid is Liquid or Gas.

Process Data			
Fluid Name		Therminol XP	◉ Liquid
Molecular Weight		18.016	○ Gas
Actual Flow	(liters/second)	20.00	
Maximum Flow	(liters/second)	50.00	
Flowing Temperature	(deg C)	270.00	
Upstream Pressure	(kPa, absolute)	700.00	
Specific Gravity		0.544	(<<< Entry Ignored)
Absolute Viscosity	(Pascal-seconds)	0.000144	(<<< Entry Ignored)
Thermal Conductivity	(W/m-K)	0.089	(<<< Entry Ignored)
Heat Capacity	(kJ/kg-K)	3.875	(<<< Entry Ignored)

Summary of Units

Property	**English (Customary US) Units**		**SI Units**	
	Liquid	**Gas**	**Liquid**	**Gas**
Flowrate	US gal/min	lb/h	liters/s	kg/h
Temperature	Deg F	Deg F	Deg C	Deg C
Pressure	psia	psia	kPa	kPa
Absolute Viscosity	cP	cP	Pascal-sec	Pascal-sec
Density	lb/ft^3	lb/ft^3	kg/m^3	kg/m^3
Length	feet	feet	meters	meters
Diameter	inches	inches	DN	DN
Head	ft water	ft water	meters water	meters water
Velocity	ft/s	ft/s	m/s	m/s

Enter the fluid name. If the fluid entered matches exactly with one in the compounds list on the PROPERTIES worksheet, the message "Entry Ignored" appears next to Molecular Weight, Specific Gravity, Absolute Viscosity, Thermal Conductivity and Heat Capacity. Otherwise "Entry Required" appears.

TIP: Use the optional pulldown list of all compounds in your database. This is especially helpful for chemicals such as n-butyl alcohol, which is actually entered in the database as "butyl alcohol, n-". Also, it's easier to find entries for compound mixtures such as "Ethylene Glycol, 40%".

Optional Pulldown List of Fluids

Therminol XP

Actual Flow is the design flowrate used in all pressure drop calculations. Maximum flow is used on the worksheet LIQFLOW, which provides the pressure drop and velocity for flows from zero to Maximum, in 10% increments. This is useful when you need to construct a system curve.

The Nominal Pressure is required for gas flows, unnecessary for liquids. The gas properties and pressure drop are highly dependent on system pressure. Enter the INLET pressure here. English units are psia (absolute pressure).

When entering a gas that isn't in the database, you *must* enter the Molecular Weight and the Absolute Viscosity. However, Specific Gravity (compared to liquid water), isn't used because *PIPESIZE* estimates it by assuming ideal gas conditions.

TIP: **Natural gas** is usually characterized by its average molecular weight or its specific gravity. Calculate molecular weight by multiplying specific gravity by 29. Use the properties of methane for viscosity, thermal conductivity and heat capacity. A little worksheet is provided to give these properties; you must enter them manually into the data entry area.

Natural Gas -- suggested properties	
Specific gravity	0.75
Molecular w eight:	21.75
Absolute viscosity	0.000011
Thermal conductivity	0.036
Heat capacity	2.220

<u>Size Selection Criteria</u> determines how *PIPESIZE* determines the pipe sizes. Choose the desired option by selecting one of the three radio buttons. If Specific Diameter is chosen, then you enter the nominal diameter of the pipe next to the prompt. For Target Velocity, enter the velocity you desire.

Economic diameter will use the results of the Peters and Timmerhaus calculation on the OPTLIQ worksheet. It's often a good starting point when sizing a new pipe. Or, use Target Velocity, which selects the pipe in your specification code which most closely matches the velocity you enter.

If you enter a specific diameter or target velocity that results in a pipe size outside the range of your pipe specification, then the closest pipe is selected and a Warning message is generated.

Size Selection Criteria

○ Economic ◉ Specific Diameter ○ Target Velocity

Diameter: 100 DN

Physical Layout is an optional section. If you know the length of the pipeline, and count of fittings, enter the data here. Another way to enter this information is to input the total equivalent length you want to use, with zero fitting count. If this section is left blank, 100 equivalent feet (meters) are assumed.

For gas pressure drop calculations, the total length of pipe is important. The calculation iterates on the total length, and is more accurate when you do enter the length.

Physical Layout			
Length of pipeline (meters)			250
90 deg Ell	0	Globe Valve	0
Long Rad. Ell	0	Gate Valve	0
45 deg Ell	0	Ball Valve (reduced por	0
180 deg Bend	0	Butterfly Valve	0
TEE-Line Flow	0	Plug Valve	0
TEE-Branch Flow	0	Angle Valve	0
Bell Mouth Inlet	0	Swing Check Valve	0
Square Mouth Inlet	0	Re-Entrant Pipe	0

Report Selection controls which of the worksheets is printed. Use the checkboxes to indicate those reports you want. Then, click on the "Print Reports" button.

Report Selection		
☐ Results Summary	☐ LIQFLOW	Print Reports
☑ Datasheet Style	☐ EquivLength	
☐ Instructions	☐ OPTLIQ	

Quick Results

Results are displayed on the Data Input worksheet. These can be printed, but the intent is to give immediate feedback so changes to the inputs can be made before finalizing the calculation and printing a datasheet. Results for three different pipes sizes are shown: the selected or recommended size is in the middle, flanked by the next smaller and next larger sizes. Use the area on the right to find out the flow rate that would result in a “desired pressure drop” through the line. All pressure drops in PIPESIZE are *frictional* pressure drop; elevation changes are not accounted for.

RESULTS			
Line		HTF-151-0136	
Service		Combustible Oil	
Material		150 lb Carbon Steel	
Fluid Name		Therminol XP	
Actual Flow	(liters/second)	20.00	
Maximum Flow	(liters/second)	50.00	
Temperature	(deg C)	270.00	
Specific Gravity		0.711	
Dynamic Viscosity	(Pascal-seconds)	0.000459	
Roughness	(millimeters)	0.04572	Calculate flow rate based on pressure drop, pipe diameter, and equivalent length
Upstream Pressure	kPa abs	700.00	Desired Pressure Drop 69 kPa
Next Smaller Size	(DN)	80.00	
Equiv. Length	(meters)	250	
Pressure Drop	(kPa/250 m)	366.7	
	(m. water)	37.5	
Velocity	(m/s)	4.2	9 l/s
Heat loss, bare pipe	(W/m)	2996.7	
Approx downstream temperature (C)		251.6	
Selected Size	(DN)	100.00	
Equiv. Length	(meters)	250	
Pressure Drop	(kPa/250 m)	91.2	
	(m. water)	9.3	
Velocity	(m/s)	2.4	17 l/s
Heat loss, bare pipe	(W/m)	3566.3	
Approx downstream temperature (C)		248.0	
Next Larger Size	(DN)	150.00	
Equiv. Length	(meters)	250	
Pressure Drop	(kPa/250 m)	11.5	
	(m. water)	1.2	
Velocity	(m/s)	1.1	49 l/s
Heat loss, bare pipe	(W/m)	4624.6	
Approx downstream temperature (C)		241.5	

Datasheet

The datasheet organizes your pipe information on a form that has the same look as datasheets used throughout the *chemengsoftware* family.

PIPELINE SIZING CALCULATION

CLIENT	LINE NO.
Sample	HTF-151-0136

REV	PREPARED BY	DATE	APPROVAL	W.O.	REQUISITION NO.	SPECIFICATION NO.
0	S. Hall	03-Apr-2013		10314		18103
1				UNIT AREA	PROCURED BY	INSTALLED BY
2				Process Utilities		

1	**General**											
2	Fluid Service						***Combustible Oil***					
3	Pipe Specification						***A: 150 lb Carbon Steel***					
4	Surface Roughness			(millimeters)			***0.04572***					
5	Insulation						***Fiberglass***					
6	Ambient Temperature			(deg C)			***30***					
7												
8	**Process Data**											
9	Fluid Pumped						***Therminol XP (liquid)***					
10	Design Flow Rate			(liters/second)			***20***					
11	Maximum Flow Rate			(liters/second)			***50***					
12	Flowing Temperature			(deg C)			***270***					
13	Nominal Pressure			(kPa, absolute)			***700***					
14	Specific Gravity						***0.71107***					
15	Viscosity			(Pascal-seconds)			***0.00046***					
16												
17	**Basis for Sizing: Specified Diameter @ 100 DN**											
18												
19		Nom.		O.D.	Wall	I.D.	Reynolds	Friction	Pressure Drop/100 equiv m			Velocity
20		Size	Sched	(mm)	(mm)	(mm)	Number	Factor	(kPa)	(m water)	(m. liq.)	(m/sec)
21		80	40	88.900	5.486	77.92	5.06E+05	0.0183	*146.69*	14.98	21.07	4.19
22	===>	***100***	40	114.30	6.020	102.2	3.86E+05	0.0177	***36.50***	***3.73***	5.24	***2.44***
23		150	40	168.27	7.112	154.0	2.56E+05	0.0173	*4.60*	0.47	0.66	1.07
24												
25	**Physical Layout**											
26	90 deg Ell		-	TEE-Line Flow		-	Globe Valve		-	Plug Valve		-
27	Long Rad. Ell		-	TEE-Brnch Flow		-	Gate Valve		-	Angle Valve		-
28	45 deg Ell		-	Bell Mouth Inlet		-	Ball Valve (red. port)		-	Swing Check Valve		-
29	180 deg Bend		-	Sq. Mouth Inlet		-	Butterfly Valve		-	Re-Entrant Pipe		-
30	Straight Feet of Pipe (measured through centerline of fittings):								***250***	meters		
31												
32	**Heat Loss**											
33		Nom.					Fiberglass Insulation Thickness					
34		Size				units	Bare	13 mm	25 mm	38 mm	51 mm	76 mm
35		80				Watts/m	2,997		148	110	90	69
36	===>	100				Watts/m	3,566		181	133	108	82
37		150				Watts/m	4,625		251	181	145	107
38		Approximate surface temperature C					262		42	38	36	34
39	**Summary of Results**											
40		Nom.	Eq Lgth	Pressure Drop			Heat Loss (Gain), Watts					
41		Size	(m)	(kPa)	m water	(m. liq.)	Bare	13 mm	25 mm	38 mm	51 mm	76 mm
42		80	250	366.72	*37.46*	52.7	749,172	n/a	37,046	27,521	22,546	17,353
43	===>	100	250	91.25	*9.32*	13.1	891,586	n/a	45,371	33,265	26,964	20,423
44		150	250	11.50	*1.17*	1.7	1,156,152	n/a	62,856	45,294	36,180	26,771
45												
46												
47												
48												
49												
50												
51												
52												

Errors and Warnings

If you see #VALUE everywhere it means that Macros are not enabled. The procedure for enabling macros depends on your version of Excel and your security settings.

If you are solving for gaseous flow and the results indicate “critical” it means that the flow rate and conditions result in a flow that exceeds critical velocity. Increase the pipe size, decrease the flow rate or decrease the gas density (increase pressure, decrease temperature).

Additional warnings are printed at the bottom of the Datasheet. The possible messages are:

Warning: Specified Size is non-standard; <SIZE> is used

Warning: Fluid Temperature exceeds maximum permitted by pipe specification

Warning: Fluid Temperature is colder than minimum permitted by pipe specification

Warning: <FLUID> not in databank; check physical properties entry

Warning: Temperature exceeds insulation maximum recommendation

Warning: Temperature lower than insulation minimum recommendation

Warning: <CODE> is not a defined pipe specification; standard IPS pipe sizes are assumed

Error: Pressure drop exceeds nominal pressure

Warning: Viscosity for gas expected to be less than 0.1 cP

Pressure Drop Calculations

The Calcs worksheet collects the data and shows the steps to calculate pressure drop due to friction. The calculations are performed for three pipe sizes: the selected size (based on program-selected “economic” size, specified size input by user, or the size that most closely achieves the velocity target input by the user). Calculations are also done in both SI and English (customary U.S.) units. There are tiny differences in the answers for SI and English units; these differences are the result of rounding and inexact conversion factors.

The Calcs worksheet also has tables with some intermediate values, units conversions, and program variables for things such as radio button selections. These are located at the bottom of the worksheet, beginning at Row 107, and contain no user-defined values.

The top portion of the Calcs worksheet contains user inputs and program lookup values. Columns D:F are in SI units, I:K are in English (U.S.) units. Whichever set of units is selected (radio buttons on the Data Input worksheet) are copied to columns N:P which is highlighted in yellow.

Although properties for both liquid and gas are shown, *PIPESIZE* uses the data set associated with liquid or gas as selected on the Data Input sheet; the other set of properties is ignored and may contain erroneous data.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1		Piping Pressure Drop Template -- For Liquids or Gases														
2		Version 3.10														
3																
4		by Stephen M. Hall, PE														
5		Copyright 1999, 2000, 2004, 2011, 2013														
6																
7																
8	This worksheet collects the data into standard forms for use by the calculations															
9																
10																
11	INPUTS and LOOKUP VALUES															
12													Selected Units: SI			
13					Value					Value					Value	
14	Symbol	Parameter	SI Units	Smaller	Target	Larger		US Units	Smaller	Target	Larger		Units	Smaller	Target	Larger
15		Nominal pipe size	DN	80	100	150		in	3.000	4.000	6.000		DN	80.000	100.000	150.000
16		Outside diameter	mm	88.90	114.30	168.28		in	3.500	4.500	6.625		mm	88.900	114.300	168.275
17		Wall thickness	mm	5.49	6.02	7.11		in	0.216	0.237	0.280		mm	5.486	6.020	7.112
18	d	Inside diameter	mm	77.93	102.26	154.05		in	3.068	4.026	6.065		mm	77.927	102.260	154.051
19		Cross-sectional area	m2	0.004769	0.008213	0.018639		ft2	0.051338	0.088405	0.200627		m2	0.004769	0.008213	0.018639
20	epsilon	Roughness	m	4.572E-05	4.572E-05	4.572E-05		ft	0.00015	0.00015	0.00015		m	0.00004572	4.572E-05	0.00004572
21																
22		Fluid name		Therminol XP	Therminol XP	herminol XP			Therminol XP	Therminol XP	Therminol XP			Therminol XP	Therminol XP	Therminol XP
23		Physical State		liquid	liquid	liquid			liquid	liquid	liquid			liquid	liquid	liquid
24		Adiabatic or Isothermal	isothermal	1	1	1			1	1	1		isothermal	1	1	1
25	R	Gas constant	N-m/kmol K	8,314.3	8,314.3	8,314.3		ft-lbf/lb-mol R	1,545.4	1,545.4	1,545.4		N-m/kmol K	8,314.3	8,314.3	8,314.3
26	gc	gc conversion factor	m/s2	1	1	1		ft/s2	32.17	32.17	32.17		m/s2	1.00	1.00	1.00
27																
28		Liquid properties														
29		Flow rate, volumetric	l/s	20.00	20.00	20.00		gpm	317.06	317.06	317.06		l/s	20.00	20.00	20.00
30	mu	Viscosity	mPa-s	0.4593	0.4593	0.4593		cP	0.4593	0.4593	0.4593		mPa-s	0.4593	0.4593	0.4593
31								lb/ft-h	1.1110	1.1110	1.1110					
32		Specific Gravity		0.711	0.711	0.711			0.711	0.711	0.711			0.711	0.711	0.711
33	ro	Density	kg/m3	711.06731	711.06731	711.06731		lb/ft3	44.3706	44.3706	44.3706		kg/m3	711.067308	711.06731	711.067308
34	W	Flow rate, mass	kg/h	51,197	51,197	51,197		lb/h	112,680	112,680	112,680		kg/h	51,197	51,197	51,197
35																
36																
37		Gas properties														
38	W	Flow rate	kg/h	NA	NA	NA		lb/h	NA	NA	NA		kg/h	NA	NA	NA
39	mu	Viscosity	mPa-s	0.4592914	0.4592914	0.4592914		cP	0.4593	0.4593	0.4593		mPa-s	0.4593	0.4593	0.4593
40								lb/ft-h	1.1110	1.1110	1.1110					
41	Mw	Molecular weight	kg/kg-mol	18.016	18.016	18.016		lb/lb-mol	18.016	18.016	18.016		kg/kg-mol	18.016	18.016	18.016
42	Tin	Temperature	C	270.00	270.00	270.00		F	518.00	518.00	518.00		C	270.00	270.00	270.00
43	p	Pressure	kPa abs	700.00	700.00	700.00		psia	101.52	101.52	101.52		kPa abs	700.00	700.00	700.00
44	gamma	Cp/Cv		1.4	1.4	1.4			1.4	1.4	1.4			1.4	1.4	1.4
45		Gas density	kg/m3	2.7920	2.7920	2.7920		lb/ft3	0.1743	0.1743	0.1743		kg/m3	2.7920	2.7920	2.7920
46																
47	L	Pipe Equivalent Length	m	250	250	250		ft	820	820	820		m	250.00	250.00	250.00
48		Target Pressure Drop	kPa	68.95	68.95	68.95		psi	10.00	10.00	10.00		kPa	68.95	68.95	68.95
49																

Figure 3: Rows 14 to 48 on the Calcs worksheet contain user inputs and program lookup values

There is one slightly hidden input in this section. For compressible flow calculations (*i.e.,* gas), you can choose to use an isothermal or adiabatic flow assumption. For isothermal, the gas is assumed to remain at constant temperature throughout the pipeline. For adiabatic, the gas cools as it expands. Isothermal conditions are usually recommended. Choose isothermal or adiabatic at cell C24.

The next portion of Calcs, from rows 59 to 85, calculates the pressure drop. The Reynolds number is computed based on the inlet conditions to the pipe segment. Friction factor is based on Reynolds number and surface roughness; it uses the Churchill correlation which covers laminar, transitional and turbulent flow regimes. Reynolds number and friction factor are calculated in VBA function subroutines.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
55																
56													**Selected Units: SI**			
57															**Value**	
58	**CALCULATIONS**												**Units**	**Smaller**	**Target**	**Larger**
59		Reynolds Number		505,910	385,527	255,916			505,076	384,892	255,495			505,910	385,527	255,916
60		Friction Factor		0.0183	0.0177	0.0173			0.0183	0.0177	0.0173			0.0183	0.0177	0.0173
61		Velocity at upstream	m/s	4.19	2.44	1.07		ft/s	13.74	7.98	3.52		m/s	4.1934	2.4351	1.0730
62																
63		For 100 m or 100 ft of equivalent length														
64		Pressure Drop	kPa/100 m	146.69	36.50	4.60		psi/100 ft	6.47	1.61	0.20		kPa/100 m	146.69	36.50	4.60
65		Pressure Drop	m water/L	14.98	3.73	0.47		ft water/L	14.94	3.72	0.47		m water/L	14.98	3.73	0.47
66		Discharge Pressure	kPa abs	553.31	663.50	695.40		psia	95.06	99.91	101.32		kPa abs	553.31	663.50	695.40
67		Discharge Temperature	C	270.00	270.00	270.00		F	518.00	518.00	518.00		C	270.00	270.00	270.00
68		Discharge Density	kg/m3	711	711	711		lb/ft3	44.4	44.4	44.4		kg/m3	711.0673	711.0673	711.0673
69		Critical (sonic) Velocity	m/s	592.39	592.39	592.39		ft/s	1,943.47	1,943.47	1,943.47		m/s	592.39	592.39	592.39
70		Velocity at discharge	m/s	4.19	2.44	1.07		ft/s	13.74	7.98	3.52		m/s	4.19	2.44	1.07
71																
72		For L equivalent length														
73		Pressure Drop	kPa/L	366.72	91.25	11.50		psi/L	53.04	13.20	1.66		kPa/L	366.72	91.25	11.50
74		Pressure Drop	m water/L	37.46	9.32	1.17		ft water/L	122.51	30.49	3.84		m water/L	37.46	9.32	1.17
75		Discharge Pressure	kPa abs	333.28	608.75	688.50		psia	48.49	88.33	99.86		kPa abs	333.28	608.75	688.50
76		Discharge Temperature	C	270.0	270.0	270.0		F	518	518	518		C	270.00	270.00	270.00
77		Discharge Density	kg/m3	711	711	711		lb/ft3	44.4	44.4	44.4		kg/m3	711.0673	711.0673	711.0673
78		Critical (sonic) Velocity	m/s	592	592	592		ft/s	1,943	1,943	1,943		m/s	592.39	592.39	592.39
79		Velocity at discharge	m/s	4.19	2.44	1.07		ft/s	13.74	7.98	3.52		m/s	4.19	2.44	1.07
80																
81		Critical Pressure	kPa absolute	369.80	369.80	369.80		psia	53.63	53.63	53.63					
82		Critical Pressure Drop	kPa	330.20	330.20	330.20		psi	47.89	47.89	47.89					
83			% Drop at Critical	0.47	0.47	0.47			0.47	0.47	0.47					
84		Flow at specified pressur	kg/h	22,200	44,504	125,379		lb/h	48,929	98,087	276,328		kg/h	22,199.55	44,503.72	125,378.96
85			l/s	8.7	17.4	49.0		gpm	138	277	780		l/s	8.67	17.39	48.98
86																

Figure 4: Rows 59 to 85 on the Calcs worksheet give calculation results for pressure drop due to friction

The pressure drop for a standard length (100 m for SI and 100 ft for English units), and also for the equivalent length derived from user inputs on the Data Input worksheet, are calculated next. The actual pressure drop calculation is done by a VBA function subroutine, using the following formulas[1]:

Incompressible flow (liquids)

$$\Delta P = \frac{f\,L U^2 \rho}{2\, g_c\, D}$$

Compressible flow, isothermal (gases)

$$\Delta P = \frac{R T Z G^2}{\overline{P} M g_c}\left[\frac{f\,L}{2D} + \ln\left(\frac{P_1}{P_2}\right)\right]$$

Compressible flow, adiabatic (gases)

$$\frac{f\,L}{D} = \frac{1}{\gamma}\left(\frac{1}{N_{Ma1}^2} - \frac{1}{N_{Ma2}^2} - \frac{(\gamma+1)}{2}\ln\left(\frac{N_{Ma2}^2 X_1}{N_{Ma1}^2 X_2}\right)\right)$$

[1] Hall, Stephen, *Rules of Thumb for Chemical Engineers*, 5th Edition, Butterworth-Heinemann (2012).

The variable definitions are:

D = pipe diameter, m or ft

f = Darcy friction factor, dimensionless

G = mass flux, kg/s-m^2 or lb/s-ft^2 = $\dfrac{W}{3600\,A}$

g_c = conversion factor, 1 m/s^2 or 32.17 ft/s^2

L = pipe equivalent length, m or ft

M = molecular weight

N_{Ma} = Mach number, dimensionless

P = absolute pressure, Pa or psia

R = gas constant, 8314.5 m^3-Pa/kgmol-K or 10.73 ft^3-psi/lbmol-R

T = absolute temperature, °K or °R

U = average fluid velocity at local conditions, m/s or ft/s = $\dfrac{G}{\rho}$

$$X = 1 + N_{Ma}^2\left[\frac{(\gamma - 1)}{2}\right]$$

Z = compressibility factor =1 for a perfect gas

γ = ratio of specific heats, C_p/C_v

μ = fluid dynamic viscosity, kg/m-s or lb/ft-h

ρ = density of gas at local conditions, kg/m^3 or lb/ft^3 = $\dfrac{P\,M}{R\,T}$

Heat Loss/Gain Calculations

PIPESIZE calculates heat loss or gain from uninsulated and insulated pipes. It displays results for heat flux (W/m or Btu/h-ft), surface temperature of the pipe or insulation, and approximate downstream temperature. VBA function subroutines performs the calculations. The primary reference for a consistent set of equations is Cao[2]. An excellent on-line article is by Haslego[3].

Inputs for the Calculations

The heat loss/gain calculations utilize SI values with conversion to U.S. Units if necessary.

Variable	**Source**	**Location in the Spreadsheet**	**Typical Values**
Reynolds number	Calculated	Calcs:Row 59	Laminar, Transitional, or Turbulent region depending on fluid properties and flow rate
Fluid Density	Properties Data Table or User Input	Calcs:D89 Cell named "RoSI"	1000 kg/m^3 (liquids) 10 kg/m^3 (gas)
Dynamic Viscosity	Properties Data Table or User Input	Calcs:D90 Cell named "DynamicVisc"	0.001 Pa-s (liquids) 0.0002 m^2/s (gas)
Thermal Conductivity	Properties Data Table or User Input	Calcs:D91 Cell named "kSI"	0.06 to 0.6 W/m-K (liquids) 0.03 W/m-K (gas)
Heat Capacity	Properties Data Table or User Input	Calcs:D92 Cell named "CpSI"	4 kJ/kg-K (liquids) 1 kJ/kg-K (gas)
Pipe Inside Diameter	Pipes Data Table	Calcs:D18:F18	5 to 760 mm
Pipe Outside Diameter	Pipes Data Table	Calcs:D16:F16	5 to 760 mm
Pipe Length	Calculated	Calcs:D47:F47	Any length, m (conservative assumption, uses equivalent length not actual pipe length)
Fluid Velocity	Calculated	Calcs:D61:F61	0.5 to 5 m/s
Temperature inside pipe	User Input	Calcs:D88 Cell named "flowing_temperatureSI"	-15°C to 500°C

[2] Cao, Eduardo, *Heat Transfer in Process Engineering*, McGraw-Hill, 2010

[3] Haslego, Chris, "Making Decisions with Insulation," http://www.cheresources.com/content/articles/heat-transfer/making-decisions-with-insulation (2010).

Variable	**Source**	**Location in the Spreadsheet**	**Typical Values**
Temperature environment	User Input	Calcs:J132 Cell named "ambientSI"	-15°C to 40°C
Wind Velocity	User Input	Calcs:D96 Cell named "Wind_Velocity"	0 to 5 m/s
Emissivity of Pipe or Insulation	Pipes Data Table	Calcs:D98 Cell named "Emissivity_Bare"	0.05 to 0.9
Thermal Conductivity of Pipe	Pipes Data Table	Calcs:D99 Cell named "_kp"	0.1 to 400 W/m-K
Thermal Conductivity of Insulation	Insulation Data Table	Calcs:D95 Cell named "insulation_conductivity"	0.02 to 0.06 W/m-K
Insulation Thickness	User Input	Calcs:N101:S101	0 to 4 in

Heat gain/loss calculations are inexact for several reasons: the film coefficient correlations are empirically based, air movement around the pipe is uneven, radiation losses depend on the surroundings, conductive heat transfer through pipe supports and structure are not included, and the effect of fittings, flanges and valves are ignored. However, the calculation in *PIPESIZE* does a good job of estimating the heat flux, surface temperature, and downstream fluid temperature given ideal conditions.

Assumptions:

- The properties of the flowing fluid are constant through the pipeline (the inside heat transfer coefficient is constant)
- Constant ambient temperature and environmental conditions (the program has no way to distinguish if the pipeline is partially outdoors and partially indoors, for example)
- The environment is dry atmospheric air (no provisions for pipes buried in soil, run through a water bath, or weather conditions such as rain or snow)
- Radiation losses based on the emittance of the pipe or insulation jacket, but if the temperature of the flowing fluid is less than that of the environment there are no radiation gains

Two VBA function subroutines perform the heat loss/gain calculations. Find them in the Module named "HeatLoss." The subroutines are self-documented, with variables, formulas, and algorithms explained in comments. Temperature-dependent equations for the thermodynamic properties of air are included in the Module. The calculations in this Module are done in SI units; if U.S. units are selected the spreadsheet converts the results. The function calls are as follows:

Inside Heat Transfer Coefficient

```
Function h_internalSI(NRe, ro, mu, k, cp, di, L, v)
' Inside heat transfer coefficient
' SI units
' h_internalSI = inside heat transfer coefficient, W/m2-C
' NRe = Reynolds number, dimensionless
' ro = density, kg/m3
' mu = kinematic viscosity, m2/s
' k = thermal conductivity, W/m-K
' cp = heat capacity, kJ/kg-C
' di = inside diameter of pipe, mm
' L = approximate pipe length, m
' v = velocity, m/s
```

This subroutine calculates the Prandl number and the Nusselt number for which the formula depends on the value of the Reynolds number. Then the inside heat transfer coefficient is calculated, for which the reference area is the inside of the pipe. See Cao as previously referenced.

Outside Heat Transfer Coefficient, and Additional Results

```
Function h_outsideSI(Calc, T1, T4, d_o, d_i, Wind, E, h_inside, kp, Optional ki, Optional kt)
' Outside heat transfer coefficient
' SI units
' h_outsideSI = outside heat transfer coefficient, W/m2-C
' Calc = return flag 0 = ho, 1 = Q, 2 = T3, 3 = U
‘ T1 = temperature inside the pipe, C
‘ T4 = temperature of the environment, C
‘ d_o = outside diameter of bare pipe, mm
‘ d_i = inside diameter of pipe, mm
‘ Wind = wind velocity, m/s
‘ E = emissivity of pipe or insulation covering, dimensionless
‘ h_inside = inside heat transfer coefficient, W/m2-C
‘ kp = thermal conductivity of pipe, W/m-K
‘ ki = thermal conductivity of insulation, W/m-K
‘ kt = insulation thickness, mm
```

This subroutine calculates the outside heat transfer coefficient. This is an iterative calculation that also determines the heat flux (W/m^2), surface temperature (°C), and overall heat transfer coefficient (W/m^2-K). The function returns any one of those values in accordance with the first parameter in the Function call (“Calc”).

The calculation makes an assumption for surface temperature and uses that to calculate a Reynolds number for the forced convection case (wind present) and from that the Nusselt number and outside heat transfer coefficient. If the wind is less than 0.5 m/s, the program calculates the no-wind convection case and compares it to the forced convection result, choosing the higher of the two answers. From this result, the overall heat transfer coefficient is calculated which is used to compute the surface temperature of the pipe (or insulation). Then, radiation losses are calculated, added to the overall coefficient, and a revised surface temperature calculated. This becomes the assumed value of the surface temperature and the entire set of calculations is repeated until the calculated surface temperature equals the assumed value.

Note that the reference area for the outside heat transfer coefficient and the overall heat transfer coefficient is the outside of the pipe or insulation.

The results are presented in a set of tables on the “Calcs” worksheet, beginning at Cell N100. The three lines in each table represent the three pipe sizes shown elsewhere in *PIPESIZE* .

	Heat Loss - W/m					
Inside Coef	Insulation Thickness (in.):					
hi	0	0.5	1	1.5	2	3
2,637	2,997		148	110	90	69
1,617	3,566		181	133	108	82
773	4,625		251	181	145	107
	0	13	25	38	51	76
	Insulation Thickness (mm):					
	Surface Temperature, C					
	0	0.5	1	1.5	2	3
	264		41	37	35	33
	262		42	38	36	34
	256		43	39	36	34
	Approximate Downstream Temperature, C					
	R	0.5	1	1.5	2	3
	251.6		269.1	269.3	269.4	269.6
	248.0		268.9	269.2	269.3	269.5
	241.5		268.5	268.9	269.1	269.3
	Outside Heat Transfer Coefficient, W/m2-C (includes radiation)					
	0	0.5	1	1.5	2	3
	46		30	29	29	28
	43		30	29	28	27
	39		28	28	27	26
	Overall Heat Transfer Coefficient, W/m2-C (includes radiation)					
	Note: corrected to the outside surface area					
	0	0.5	1	1.5	2	3
	12.5		1.4	0.9	0.6	0.4
	14.9		1.5	0.93	0.66	0.41
	19.3		1.5	1.0	0.7	0.4

Figure 5: Heat Loss/Gain Results (Therminol XP at 350°C, 50 DN pipe, 10°C environment, no wind)

Insulation Worksheet

Data for insulation are tabulated and the thermal conductivity at the average of the fluid temperature and ambient temperature is calculated. This result is used in the heat loss/gain calculations. Regression coefficients for thermal conductivity are in U.S. units of Btu-in/(h-ft^2-F). The formula is:

$$k = m + pT + sT^2 + tT^3 + uT^4$$

Where the coefficients are in the table, and T is the average temperature, °F. Note that the use of all coefficients is optional; for a fixed thermal conductivity simply enter it in the "m" coefficient and leave the others blank.

Insulation Material	Min. Thickness (in)	Thermal Conductivity Coefficients m	p	s	t	u	Maximum Temperature (°F)	Minimum Temperature (°F)	Thermal Conductivity, K [Btu*in/(h*ft²*°F)]	W/m-K
Calcium Silicate	1	0.369	1.58E-04	3.92E-07	9.40E-11	0.00E+00	1000	250	0.384	0.055
Cellular glass	1	0.289	5.14E-04	4.36E-07	2.27E-10	2.76E-13	900	-450	0.332	0.048
Elastometric foam	0.5						200	-40	0.290	0.042
Fiberglass	1	0.195	4.25E-04	0.00E+00	0.00E+00	0.00E+00	850	42	0.228	0.033
Mineral Wool	1	0.228	3.72E-04	6.00E-07	0.00E+00	0.00E+00	1200	42	0.261	0.038
Perlite, expanded	1	0.388	4.73E-04	3.06E-07	-8.00E-11	0.00E+00	1000	250	0.427	0.062
Phenolic foam	1	0.116667	6.67E-04				300	75	0.169	0.024
Polystyrene foam	1						165	-65	0.230	0.033
Polyurethane/ Polyisocyanurate foams	1	0.174	-1.55E-04	-3.39E-07	8.38E-09	1.82E-11	250	-200	0.164	0.024

The minimum and maximum temperatures are used only for determining if a Warning message should be displayed.

The worksheet also includes values for emissivity for various insulation coverings. The values in the "Range" column are recommended guidance numbers. The emissivity used in the radiative heat transfer calculation is in the right-hand column. If you add additional materials to this table, do it by inserting a row, entering your data, and then sorting the list alphabetically. The table is a named range ("Insulation_Cover_Emittance"). The easiest way to add data while preserving the range's name is by inserting a row into the middle of the table.

Material	Range	Value for Calc
Aluminum jacketing, gray-dull	.10 to .40	0.2
Aluminum jacketing, oxidized	.10 to .60	0.4
Aluminum jacketing, polished	.03 to .10	0.1
Aluminum paint, new	.20 to .30	0.25
Aluminum paint, weathered	.40 to .70	0.5
Asbestos fabric, white		0.78
Asphalt mastic	.90 to .95	0.95
Galvanized steel jacketing, dull	.20 to .60	0.5
Galvanized steel jacketing, new	.06 to .10	0.1
Paint, black	.90 to .95	0.95
Paint, gray	.80 to .90	0.85
Paint, green	.65 to .80	0.75
Paint, white	.55 to .70	0.6
Plastic, black		0.95
Plastic, white		0.84
PVA mastic, black	.85 to .95	0.9
PVA mastic, gray	.85 to .90	0.9
PVA mastic, green	.70 to .80	0.75
PVA mastic, white	.60 to .79	0.75
Stainless steel jacket, mill finish	.35 to .40	0.4
Stainless steel jacket, oxidized	.80 to .85	0.85
Stainless steel jacket, polished	.22 to .26	0.25
Styrofoam		0.6

Properties Worksheet

Find and add physical property data on the Properties worksheet. Most of the data are correlated to temperature, so the properties table contains equation coefficients for liquids and gases. You can new compounds to the list, and if you have properties at three temperatures, the spreadsheet determines the coefficients for you.

The Properties sheet has three parts. 1) Upper left quadrant gives brief instructions and shows the results for the current fluid (from the Data Input worksheet); 2) Lower right quadrant tabulates the fluids and their coefficients; 3) Upper right quadrant is used for entering new fluids into the list.

Property Results (see Figure 6*)*

The current fluid, or “Compound Name,” as entered on the Data Input worksheet is displayed in Cell C29. *PIPESIZE* looks up the fluid in the Properties Table and reports the result in Cell C30. If the there is an exact match, the properties from the table are used in the calculations. Otherwise, the “Entry Required” prompts appear on the Data Input sheet and the properties returned from this worksheet are ignored.

The values listed in Column D, Rows 28 to 38, are the coefficients pulled from the data table. They are used to calculate viscosity, specific gravity, thermal conductivity, and heat capacity in C33, C34, C37, and C38. Notice that these values are all in American units; conversion to SI is performed on the Calculations worksheet. Also notice that temperature is in Celsius for each of the correlations except for viscosity where Kelvin is used. Apologies for the mixed units of measure, but be careful when working on the Properties worksheet.

	A	B	C	D	E
1			**Physical Property Data for Fluid Flow**		
2					
3	The data on this worksheet are used for estimating viscosity and specific gravity.				
4	You can enter new compounds in the table. To do so, insert rows in the table in				
5	the appropriate places; compound names must be in alphabetical order.				
6	Enter coefficients for the viscosity equation using one of the equations listed below.				
7					
8	Units are:				
9		temperature	deg K (for viscosity equation); deg C (for specific gravity)		
10		viscosity	centipoise (cP)		
11		specific gravity	dimensionless (compared to water at 4 or 20 deg C)		
12					
13	Viscosity equations:				
14					
15	1	μ = b T^m			
16					
17	2	ln μ = b + m / T	Andrade equation		
18					
19	3	log μ = b + m / T + c T + d T^2	Use this equation for Carl Yaws data		
20					
21	4	ln μ = b + m / (T+c)			
22					
23	5	μ = b + cT + dT^2	Normally used for gas viscosity		
24					
25	6	log μ = b * ((1/T) - (1/m))	Use this equation for Reid/Sherwood data		
26					
27			**Calculations**		
28				TRUE	
29	Compound Name:		**Water**	106	
30	Name found in Properties Table:		Water	Coeff.:	
31	Temperature (deg C):		26.66666667	-6.2759	
32	Viscosity Equation:		2	1848	
33	Absolute Viscosity (cP):		0.8967	0	
34	Specific Gravity:		0.995337588	0	
35	Rato of Cp to Cv		1.31	0.36376	
36	Molecular Weight		18.02	1.9E-05	
37	Thermal conductivity, Btu/ft-h-F		0.36	0.96	
38	Heat capacity, Btu/lb-F		0.98	0.00085	

Figure 6: Property Results in the upper left quadrant of the Properties worksheet

Properties Data Table (see Figure 7*)*

Data are tabulated for liquids and gases as defined in the column headers. **Compounds must remain in alphabetical order**. The data fields (columns) are defined here.

Column	Name	Content	Equation
F	Compound	Fluid name, in alphabetical order	Not applicable
G	Viscosity Equation	Number corresponding to the equation used for liquid viscosity. See Cells A15:A25	See equations in Cells B15:B25. Viscosity data published in the literature will fit one of these equations. New compounds are fit to Equation 4 (see discussion in the next section).
H:K	b, m, c, d	Coefficients for the liquid viscosity equation	
L	Liquid Sp. Gr.	Intercept, b	Specific Gravity = m t + b, where t = °C
M	Sp Gr slope	Slope, m	
N	Mol. Wt.	Molecular weight	Required for gases
O:Q	b, c, d	Coefficients for the gas viscosity equation, always Equation 5	See Equation 5 in Cell B23
R	C_p/C_v	Ratio of specific heats	Required for gases
S	Liquid Thermal Conductivity	Intercept, b	k = m t + b
T	Thermal Conductivity Slope	Slope, m	
U	Liquid Heat Capacity	Intercept, b	C_p = m t + b
V	Heat Capacity Slope	Slope, m	
W	Gaseous Thermal Conductivity	Intercept, b	k = m t + b
X	Thermal Conductivity Slope	Slope, m	
Y	Gaseous Heat Capacity	Intercept, b	C_p = m t + b
Z	Heat Capacity Slope	Slope, m	

The straight line regressions for specific gravity, thermal conductivity, and heat capacity are rough approximations for the actual values. There are more accurate correlations. However, for the purposes of the *PIPESIZE* spreadsheet, these approximations are better than needed to obtain good results for pressure drop and heat transfer.

Physical Property Data Table

Compound	Viscosity Equation	b	m	c	d	Liquid Sp. Gr.	Sp Gr slope	Mol. Wt.	b	c	d	Cp/Cv	Liquid Thermal Conductivity	Thermal Conductivity slope	Liquid Heat Capacity	Heat Capacity slope	Gaseous Thermal Conductivity	Thermal Conductivity slope	Gaseous Heat Capacity	Heat Capacity slope
Acetaldehyde	1	51400000	-3.39			0.778		44.05					0.106228714	-0.000310889	0.5217652	-0.0015532				
Acetic Acid	1	1.159E+11	-4.445			1.049		60.05					0.0940545	-0.000107349	0.48					
Acetone	2	-3.677	750.06			0.79		58.08					0.093930636	-0.000184971	0.514					
Acetonitrile	1	3851000	-2.849			0.782							0.125414258	-0.000394509	0.53					
Acrylic Acid	1	1.51E+10	-4.0894			1.051		72.07					0.095231214	-0.000166185	0.4992833					
Air	1	1.78E-01				0.874		29	3.04E+01	4.99E-01	-1.09E-04	1.4	-0.105095994	-0.000959815	1.2390398	0.0038766	0.01428	0.000039	0.23645	0.000043
Ammonia	3	-8.591	8.76E+02	2.68E-02	-3.61E-05	0.634	-0.0015936	17.03	-9.372	0.3899	-4.405E-05	1.31	0.29969042	-0.00123621	1.1360123	0.0033359	0.011790223	8.12552E-05	0.4889969	0.0004438
Amyl Alcohol, t-	3	-25.3557	4.23E+03	5.08E-02	-3.84E-05	0.809		88.15					0.088379508	-3.65658E-05	0.4797082	0.0006794				
Aniline	1	1.689E+21	-8.325			1.022		93.14					0.102206166	-0.000112909	0.514					
Benzene	1	1.287E+09	-3.768			0.885		78.11					0.085353999	-0.000168234	0.2322975	0.0007235				
Brine, CaCl2, 25%	1	2.001E+23	-9.278			1.2284							0.28		0.689					
Bromine	3	-1.4	387.5	-4.16E-04	-5.21E-07	3.119		159.83				1.28	0.000117169	-0.00017716	0.11		0.002428253	9.81647E-06	0.0540505	5.986E-06
Butane, iso-	4	-16.740223	2.03E+04	1.07E+03		0.572	-0.00123	58.12	-2.0985093	0.0336529		1.39	0.060586958	-0.000215885	0.5760189	0.0015614	0.006692702	8.31957E-05	0.3739031	0.0010125
Butane, n-	6	265.84	1.60E+02			0.594	-0.0011325	58.12	-1.0622198	0.029457		1.39	0.06968483	-0.000259709	0.5703173	0.0011016	0.006692702	8.31957E-05	0.3865948	0.000954
Butyl Acetate, iso	2	-4.7686	1303.2			0.875		116.16					0.0867		0.4458833	0.0006638				
Butyl Acetate, n-	1	2.06E+10	-4.233			0.898		116.16					0.081451754	-0.000118421	0.4476211	0.0005589				
Butyl Alcohol, n-	1	2.25E+18	-7.247			0.810		74.12					0.091425819	-0.000104046	0.687					
Butyl Alcohol, tert	2	-11.935	4015.7			0.787		74.12					0.06425	-7.5E-05	0.6453667	0.0029925				
Calflo AF	4	-4.639127	1997.487	-60.19		0.732							0.082706429	-3.00429E-05	0.4417857	0.0007786				
Calflo FG	4	-4.0640252	1707.8923	-54.278889		0.8601282	-0.000476						0.07995	-3.12E-05	0.43	0.0008				
Calflo HTF	4	-4.4855893	1997.9578	-61.14		0.8683578	-0.000511						0.08314	-3.00571E-05	0.4417857	0.0007786				
Carbon Dioxide	6	578.08	185.24			0.777		44.01	25.45	4.55E-01	-8.65E-05	1.304	0.063645888	-0.000717065	0.5466929	0.0016632	0.008835453	4.62428E-05	0.1992282	0.0001687
Carbon Monoxide	1	0.17				0.79		28.01	32.28	4.75E-01	-9.65E-05	1.404					0.013483497	3.97192E-05	0.2464909	4.353E-05
Chemtherm 550	4	-5.1158219	2128.6535	-63.356667		0.8846154	-0.0007212						0.071541333	-7.83E-05	0.40832	0.000918				
Chlorine	1	19610	-1.934			1.563		70.906	5.175	4.57E-01	-8.85E-05	1.355	0.084683643	-0.000341822			0.004703846	1.83472E-05	0.1144586	2.443E-05
Chlorobenzene	1	173500000	-3.376			1.106		112.56					0.077328516	-0.00011763	0.314893	0.0003839				
Chloroform	2	-3.406	832.5			1.489		119.39					0.069749518	-0.000157514	0.251					
Cyclohexane	3	4.7423	-2.53E+02	-1.69E-02	1.25E-05	0.779		84.16					0.072121145	-0.000165409	1.85		0.001048094	6.55271E-05	0.1145399	2.167E-05
Dimethylformamide	2	-3.6999	1033			0.967	-0.0009	73.09					0.111685427	-0.000152621	0.485					
Dowtherm A	4	-4.1427481	1425.6389	-31.141111		1.1155691	-0.0010733	166					0.081977996	-9.24151E-05	0.3611309	0.0006836				
Dowtherm G	4	-3.8039418	1436.9205	-39.29		1.1076496	-0.0007356						0.080847571	-6.64714E-05	0.3664686	0.0005503				
Dowtherm HT	4	-3.202376	1201.1026	-52.801111		0.9962179	-0.0006635						0.074988069	-5.87861E-05	0.3399144	0.0009198				
Dowtherm J	4	-4.518763	1204.2332	-16.701111		0.8799542	-0.0008674						0.076629155	-0.000122683	0.4229232	0.0009371				
Dynalene PG - 20 Vol%	4	-3.7439459	656.32342	-145.48573		1.028418	-0.0005305						0.270480868	0.000478714	0.9391748	0.0005248				
Dynalene PG - 40 Vol%	4	-4.0578688	747.14728	-159.32119		1.0457626	-0.0006083						0.221360107	0.0003194	0.869017	0.0007863				
Dynalene PG - 60 Vol%	4	-4.2709737	936.23424	-150.36144		1.0563829	-0.0006522						0.180596328	0.000172828	0.7770787	0.0010535				
Dynalene PG - 80 Vol%	4	-4.6103044	1143.8308	-143.2188		1.0690127	-0.0007901						0.148864349	1.52607E-06	0.6601533	0.0012068				
Dynalene Solar Glycol	4	-4.3458108	1235.458	-92.019134		1.0468234	-0.0006419						0.19355814	0.000217674	0.8673559	0.0014028				
Ethane	3	-4.444	2.90E+02	1.91E-02	-4.16E-05	0.386	-0.0018564	30.07	5.576	3.06E-01	-5.31E-05	1.44	0.051125	-0.000405804	0.7559331	0.0020433	0.009171546	9.57473E-05	0.4019925	0.0008845
Ethyl Acetate	1	5448000	-2.866			0.901		88.1					0.088439306	-0.000208092	0.475					
Ethyl Alcohol	1	5.276E+13	-5.53			0.80636	-0.0008456	46.07					0.101734104	-0.00016185	0.6					
Ethyl Alcohol, 40%	1	4.949E+23	-9.4045			0.93518														
Ethyl Hexanol, 2-	6	1798	351.17			0.833		130.231					0.0773		0.5104	0.002385				
Ethylene	3	-7.706	4.68E+02	3.73E-02	-7.63E-05	0.356	-0.0021018	28.05	3.586	3.51E-01	-8.06E-05	1.67	0.047449292	-0.000619292	1.0524909	0.0050241	0.01148284	8.30925E-05	0.3551041	0.000701
Ethylene Glycol	2	-7.7786	3139.8			1.114							0.147976879	0	0.555					
Ethylene Glycol, 40%	2	-10.12	3266			1.045														
Formamide	2	-7.8437	2693			1.139		45.04												
Formic Acid	2	-5.1096	1671.3			1.226		46.03					0.159405556	-4.75E-05	0.4963429	0.0006943				
Gasoline, 56°API	1	19163000	-3.0327			0.8							0.078		0.53					
Helium	1	0.0035962				0.125		4.0026	197.17			1.66					0.080651234	0.000205872	1.2407083	-1.815E-14
Heptane	3	-5.7782	8.06E+02	1.34E-02	-1.48E-05	0.684		100.21					0.084161944	-0.00017175	0.51208	0.000792				
Hexane, n-	1	9.00E+06	-3.01E+00			0.659		86.17					0.073845604	-0.000190879	0.5198396	0.0009979				
Hitec	4	-1.9675258	1447.9959	-105.57889		2.0768205	-0.0007269						0.35	0	0.373	0				
Hydrazine	3	-8.024	1299	1.61E-02	-1.33E-05	1.008		32.05							0.7247167	0.0005513				
Hydrochloric Acid, 31.5%	1	1.891E+09	-3.6348			1.16														
Hydrogen	1	0.013				0.071		2.0159	21.87	2.22E-01	-3.75E-05	1.41					0.09567148	0.000316061	3.4144472	0.0001846
Hydrogen Bromide	3	-9.238	866.7	3.43E-02	-5.17E-05	2.16		80.92												
Hydrogen Chloride	5	-9.554		5.45E-01	-9.66E-05	1.193		36.46	-9.554	5.45E-01	-9.66E-05	1.4					0.089017341		0.1897986	1.707E-05
Isopropyl Alcohol	1	5.009E+23	-9.451			0.786		60.09					0.081242907	-0.000132631	0.5759664	0.0026252				

Figure 7: Physical Properties Data Table in the lower right quadrant of the Properties worksheet

Entering New Fluids into the Properties Table (see Figure 8*)*

This is a handy tool for determining the regression coefficients for each of the temperature-dependant physical properties. The input section, within the black boxes, has three parts: units of measure, liquid properties, and gaseous properties.

After entering data, the program converts it to the US Units used in the Physical Properties Data Table and fits the data to straight lines or, in the case of viscosity, to Equation 4 or Equation 5. The viscosity equations are not, technically “fit” since there are three coefficients and three data points. However, as long as your initial viscosity data is good, the resulting equations will do an excellent job interpolating to other values.

When done, click on the “Add compound or update data” button. If your fluid is not already in the Properties Table, the macro inserts a new row and copies the values into the table. However, if your fluid is already in the table, the macro gives you a choice of overwriting existing data, or just adding any new data that you may have entered. For instance, there is no data for gaseous acetone in the table. If you enter values for gaseous acetone then click the button, you could add that data to the table without affecting the existing values for liquid acetone.

Alternatively, you can Unprotect the worksheet (there is no password) and enter or edit the data in the Properties Table directly. To use a single constant value for any property, just enter it (in the proper units) under the “b” column. For example, the value for specific gravity of acetaldehyde is a constant 0.778 in the distribution version of *PIPESIZE* (see Cell L41).

To delete a fluid from the Properties table, first Unprotect the worksheet (there is no password), highlight the row you want to delete, and use the Excel menu selection Delete… Delete Sheet Rows.

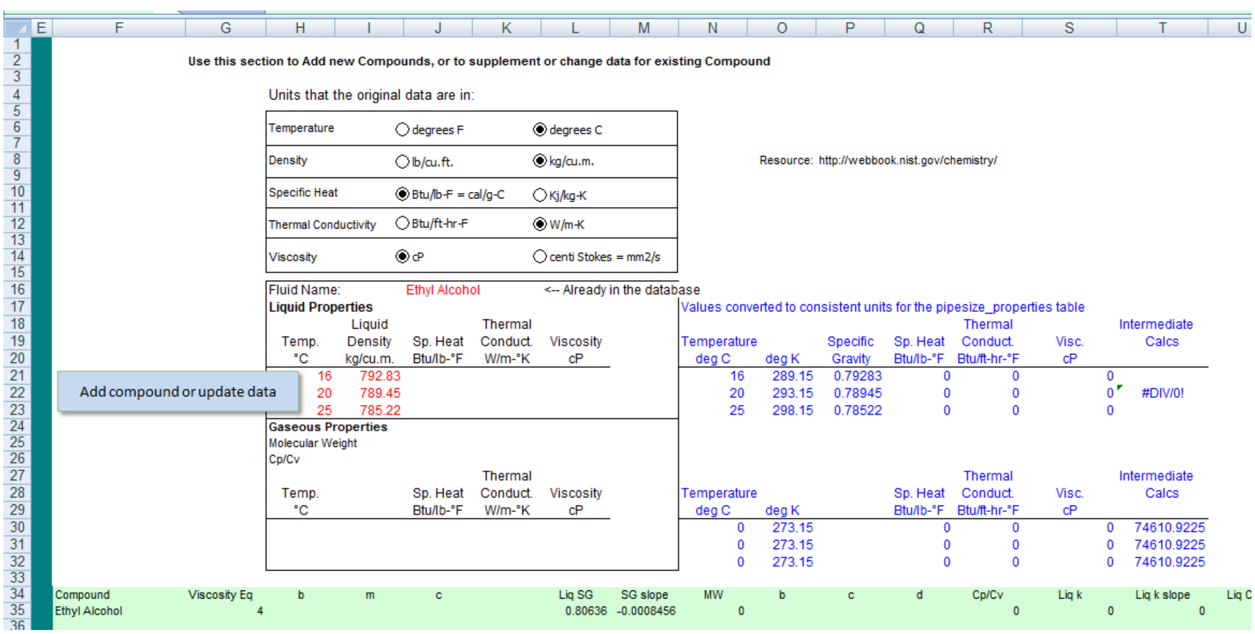

Figure 8: Enter New Fluids or Data in the upper right quadrant of the Properties worksheet

Line List Worksheet

The Line List is a flexible repository for your calculations. Each column that corresponds to a workbook variable is named. In the example below, Cell C9 is selected. Notice that the cell is named "LineList_Spec". Each column is similarly named; this is how the VBA Macro finds its way around the sheet. You may rearrange the columns as long as the column's named cells are retained.

You may also insert blank rows (to group lines into plant areas for example, and add other explanatory information and notes.

When the "Save Current Calc to Line List" is selected, a new line of data is added immediately below the last line. If there are notes or other information below your line list, the Macro is somewhat intelligent: it finds the last piece of data in the "Pressure Out" column and puts the new line there.

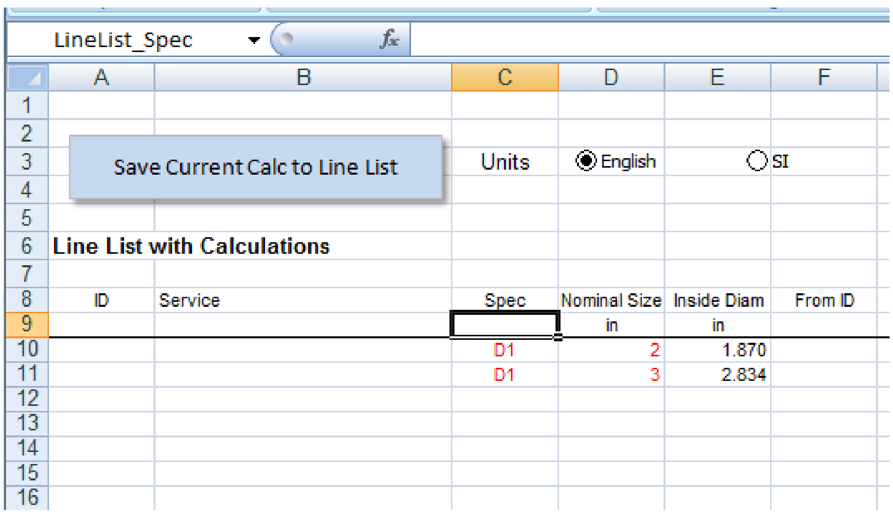

Figure 9: Line List worksheet

To restore a line to the calculation page ("Data Input"), you select any cell in the Row with the line you want to restore. Click "Restore Selected Line to Calc Sheet." The following things will happen:

- Macro checks to be sure a valid row is selected
- The Fluid name is transferred to "Data Input" and the Macro checks to see if the Fluid is in the database.
- If the Fluid is not in the database, the viscosity and density values, and Molecular Weight if it's a gas, are transferred to the "Entry Required" cells on "Data Input"
- The other data is transferred
- Since the fitting count, if any, is not saved to the Line List, only the total equivalent length is transferred. To ensure that the correct equivalent length is utilized, the number of each of the fitting types is reset to zero.
- The "Specific Diameter" calculation method is selected, and the nominal pipe size is transferred to "Data Input" as that diameter

LIQFLOW Worksheet

This datasheet presents ten flow calculations for each of the three pipe sizes. It uses the user input in cell F34 on the Data Input worksheet as the maximum flow rate, and calculates results at ten equal intervals.

				EFFECT OF FLOW VARIATION		
				CLIENT Sample	LINE NO. HTF-151-0136	
REV	PREPARED BY	DATE	APPROVAL	W.O. 10314	REQUISITION NO.	SPECIFICATION NO. 18103
0	S. Hall	02-Apr-2013		UNIT AREA Process Utilities	PROCURED BY	INSTALLED BY
1						
2						

1	**General**									
2	Fluid Service		***Combustible Oil***							
3	Pipe Specification		***A: 150 lb Carbon Steel***							
4	Surface Roughness	(millimeters)	***0.04572***							
5	Insulation		***Fiberglass***							
6	Ambient Temperature	(deg C)	***30***							
7										
8	**Process Data**									
9	Fluid Pumped		***Therminol XP (liquid)***							
10	Design Flow Rate	(liters/second)	***20***							
11	Maximum Flow Rate	(liters/second)	***50***							
12	Flowing Temperature	(deg C)	***270***							
13	Nominal Pressure	(kPa, absolute)	***700***							
14	Specific Gravity		***0.71107***							
15	Viscosity	(m-Pascal-seconds)	***0.45929***							
16										
17	**Smaller Pipe Size**		**80**	DN	Flow	Reynolds	Friction	DeltaP/100 equiv m		Velocity
18	Schedule		40		(kg/h)	Number	Factor	(kPa)	(m water)	(m/s)
19	Outside Diameter	(mm)	88.900		12,799	126,478	0.0202	10.1	1.04	1.05
20	Wall Thickness	(mm)	5.486		25,598	252,956	0.0190	38.2	3.90	2.10
21	Inside Diameter	(mm)	77.927		38,398	379,434	0.0185	83.7	8.54	3.15
22	Flow Area	(m2)	0.005		51,197	505,911	0.0183	146.7	14.98	4.19
23					63,996	632,389	0.0181	227.1	23.19	5.24
24					76,795	758,867	0.0180	324.9	33.17	6.29
25					89,594	885,345	0.0179	440.2	44.94	7.34
26					102,394	1,011,823	0.0178	572.8	58.48	8.39
27					115,193	1,138,301	0.0178	722.8	73.79	9.44
28					127,992	1,264,779	0.0178	890.2	90.88	10.48
29	**Selected Pipe Size**		**100**	DN	Flow	Reynolds	Friction	DeltaP/100 equiv m		Velocity
30	Schedule		40		(kg/h)	Number	Factor	(kPa)	(m water)	(m/s)
31	Outside Diameter	(mm)	114.30		12,799	96,382	0.0203	2.6	0.27	0.61
32	Wall Thickness	(mm)	6.020		25,598	192,764	0.0187	9.6	0.98	1.22
33	Inside Diameter	(mm)	102.26		38,398	289,146	0.0181	21.0	2.14	1.83
34	Flow Area	(m2)	0.008		51,197	385,529	0.0177	36.5	3.73	2.44
35					63,996	481,911	0.0175	56.3	5.75	3.04
36					76,795	578,293	0.0173	80.3	8.19	3.65
37					89,594	674,675	0.0172	108.5	11.07	4.26
38					102,394	771,057	0.0171	140.9	14.39	4.87
39					115,193	867,439	0.0170	177.5	18.13	5.48
40					127,992	963,822	0.0169	218.4	22.29	6.09
41	**Next Larger Pipe Size**		**150**	DN	Flow	Reynolds	Friction	DeltaP/100 equiv m		Velocity
42	Schedule		40		(kg/h)	Number	Factor	(kPa)	(m water)	(m/s)
43	Outside Diameter	(mm)	168.27		12,799	63,979	0.0210	0.3	0.04	0.27
44	Wall Thickness	(mm)	7.112		25,598	127,959	0.0188	1.2	0.13	0.54
45	Inside Diameter	(mm)	154.05		38,398	191,938	0.0179	2.7	0.27	0.80
46	Flow Area	(m2)	0.019		51,197	255,918	0.0173	4.6	0.47	1.07
47					63,996	319,897	0.0169	7.0	0.72	1.34
48					76,795	383,877	0.0167	10.0	1.02	1.61
49					89,594	447,856	0.0165	13.4	1.37	1.88
50					102,394	511,836	0.0163	17.3	1.77	2.15
51					115,193	575,815	0.0162	21.8	2.22	2.41
52					127,992	639,795	0.0161	26.7	2.73	2.68

OPTLIQ Worksheet

When the “Economic” pipe sizing criteria is selected on the Data Input worksheet, the result is calculated on this OPTLIQ sheet.

chemeng software.com				SELECTED PIPE DIAMETER		
				CLIENT Sample	*LINE NO.* HTF-151-0136	
REV	PREPARED BY	DATE	APPROVAL	*W.O.* 10314	*REQUISITION NO.*	*SPECIFICATION NO.* 18103
0	S. Hall	02-Apr-2013				
1				*UNIT* Process	*AREA* Utilities	
2					*PROCURED BY*	*INSTALLED BY*

1	**General**				
2	Fluid Service		***Combustible Oil***		
3	Pipe Specification		***A: 150 lb Carbon Steel***		
4	Surface Roughness	(millimeters)	***0.04572***		
5	Insulation		***Fiberglass***		
6	Ambient Temperature	(deg C)	***30***		
7					
8	**Process Data**				
9	Fluid Pumped		***Therminol XP (liquid)***		
10	Design Flow Rate	(liters/second)	***20***		
11	Maximum Flow Rate	(liters/second)	***50***		
12	Flowing Temperature	(deg C)	***270***		
13	Nominal Pressure	(kPa, absolute)	***700***		
14	Specific Gravity		***0.71107***		
15	Viscosity	(Pascal-seconds)	***0.00046***		
16					
17	**Economic Data**				
18	Purchase cost of new pipe, 1 inch diameter, $/ft				$1.75
19	Ratio of costs for fittings & installation to purch. cost of pipe				5
20	Factor relating pipe cost to diameter (exponential)				1.30
21	Frictional loss due to fittings and bends, % of straight pipe				35%
22	Operation, hours/yr				8,000
23	Cost of electricity, $/kw hr				$0.15
24	Efficiency of motor and pump, %				60%
25	Annual fixed charges for maintenance, % of pipe cost				20%
26					
27	**Basis for Sizing: Specified Diameter @ 100 DN**				
28	Optimum diameter calculated using Peters & Timmerhaus formula				4.21
29	Closest pipe size from specified material class				4
30					
31			Smaller	Selected	Next Larger
32			Size	Size	Size
33	Actual Size	inch nominal size	3	4	6
34		inch actual inside diame	3.068	4.026	6.065
35	Velocity	feet/second	13.74	7.98	3.52
36	Reynolds No.		505,076	384,892	255,495
37	Friction Factor		0.0183	0.0177	0.0173
38	Pressure Drop	psi/100 equiv ft	6.466	1.609	0.203
39					
40	Calculated Costs, $ per year per foot of installed piping:				
41			3	4	6
42	Pumping Cost	(power)	$25.83	$6.93	$0.95
43	Initial Piping	(capital expenditure)	$43.80	$63.66	$107.84
44	Annual Piping	(maintenance)	$8.76	$12.73	$21.57
45	Total		$34.59	$19.66	$22.52
47					
48					
49					
50	Reference:	Peters & Timmerhaus			
51		Plant Design and Economics for Chemical Engineers			
52					
53					

Equivalent Length Worksheet

This worksheet shows how the equivalent length is calculated.

For most fittings and sizes, the equivalent length is obtained from a table of values (using U.S. units), at Cell Q91 in the worksheet. To edit the values first Unprotect the sheet. If the table lacks the value then the "K" method is used to estimate the equivalent length.

If you don't know the number of fittings, then a good rule of thumb is to add 35% to 40% to the physical length of pipe to account for the fittings. In this case, first estimate the total length of pipe. Multiply by 1.35 or 1.4. Enter the value on the Data Input worksheet (Cell G47 named "Pipe_Length"). Put a value of 0 for all fittings.

The results are tabulated in the data sheet on this worksheet.

Valves

The worksheet has instructions and an example for calculating the equivalent length of a valve for which only the flow coefficient (Cv) is known. You can either edit the table of values with the equivalent length of your specific valve, or simply add the calculated equivalent length to the overall pipe length entered on the Data Input worksheet (Cell G47 named "Pipe_Length").

Equipment

Equipment manufacturers often provide a pressure drop at specified flow conditions. For example, the tube-side pressure drop for a heat exchanger is reported on the heat exchanger datasheet, at the flow rate given on the datasheet. You can find the equivalent length by entering the flow data (fluid, flow rate, temperature, density, viscosity) on the Data Input worksheet, then change the pipe length (all fittings set to 0) until the calculated pressure drop equals the pressure drop reported by the equipment manufacturer.

If your pressure drop data is for water at 60°F (which is the case for valves – the flow coefficient is the flow rate of water at 60°F, in gpm, that results in a pressure drop of 1 psi), then use the calculator on the Equivalent Length worksheet to determine the equivalent length. This calculator utilizes a Function subroutine called EqLUSa which has four arguments:

Function EqLUSa(W, Pdrop, d, epsilon), where

W = flow rate, lb/h (= gpm x 500)

Pdrop = known pressure drop (reported by equipment manufacturer), psi

d = inside pipe diameter of the pipe segment that the equipment is installed in, inch

epsilon = roughness of pipe that equipment is installed in, ft www.chemengsoftware.com

EQUIVALENT LENGTH OF PIPE

CLIENT	LINE NO.	
Sample	HTF-151-0136	
W.O.	REQUISITION NO.	SPECIFICATION NO.
10314		18103
UNIT / AREA	PROCURED BY	INSTALLED BY
Process / Utilities		

REV	PREPARED BY	DATE	APPROVAL
0	S. Hall	02-Apr-2013	
1			
2			

General	
Fluid Service	***Combustible Oil***
Pipe Specification	***A: 150 lb Carbon Steel***

Pipe Size	80 **DN**		100 **DN**		150 **DN**	
Fittings	Qty	Equiv. M.	Qty	Equiv. M.	Qty	Equiv. M.
90 deg Ell	0	0.0	0	0.0	0	0.0
Long Rad. Ell	0	0.0	0	0.0	0	0.0
45 deg Ell	0	0.0	0	0.0	0	0.0
TEE-Line Flow	0	0.0	0	0.0	0	0.0
TEE-Branch Flow	0	0.0	0	0.0	0	0.0
180 deg Bend	0	0.0	0	0.0	0	0.0
Globe Valve	0	0.0	0	0.0	0	0.0
Gate Valve	0	0.0	0	0.0	0	0.0
Ball Valve (red. port)	0	0.0	0	0.0	0	0.0
Butterfly Valve	0	0.0	0	0.0	0	0.0
Plug Valve	0	0.0	0	0.0	0	0.0
Angle Valve	0	0.0	0	0.0	0	0.0
Swing Check Valve	0	0.0	0	0.0	0	0.0
Bell Mouth Inlet	0	0.0	0	0.0	0	0.0
Square Mouth Inlet	0	0.0	0	0.0	0	0.0
Re-Entrant Pipe	0	0.0	0	0.0	0	0.0
Straight Pipe		250		250		250
Total Equiv Meters		250		250		250

Equivalent lengths are calculated using a table of values.
If the fitting/size combination does not appear in the table, the "K Value" method is used.
"K Value" data are from the Hydraulic Institute, Pipe Friction Manual, regressed.

Velocities Worksheet

This worksheet tabulates recommended velocities for various services. The information contained on this sheet was compiled from several sources, and is intended to be a simple starting point, not a definitive declaration.

*** END OF DOCUMENT ***