

COMMERCIAL GAS PIPE SIZING

PART 2 – Using the Pressure Drop Calculator (PDC)

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About the PDC (version 4.2)

The PDC spreadsheet runs on Microsoft Excel and is written in VBA. These notes assume a basic working familiarity with Excel.

Please note that you may have to click **Enable Content** and/or **Enable Macros** etc. to use the PDC depending on the security settings of your computer.

The PDC can calculate steady-state working pressure losses in low pressure, medium pressure and high pressure natural gas (NG) and LPG (propane) pipework systems. The following pipe materials are supported:

- Steel
- PE
- Copper
- Other (an unspecified rough pipe material of high friction factor)

The PDC can:

- Model systems or sections of up to 58 pipe legs
- Automatically handle additional equivalent lengths of many types of fitting
- Calculate gas flow rates through pipe legs
- Give user warnings if the gas speed in any pipe exceeds 20 m / s (the maximum permitted before a pipework filter is required)
- Calculate installation volume (IV)

The PDC uses an iterative method to solve the Colebrook-White equation for friction factor which is then used in the general fluid flow equation to estimate pressure loss.

The PDC cannot calculate pressure losses in a pipework ring main.

Pressure loss calculations are always approximations. Real-world variables such as pipe condition, nominal diameter vs internal diameter, quality of pipe jointing etc. should be taken into account. Use error tolerances which will overestimate pressure losses rather than underestimate them. The double-checking of all entered data is essential. Confirmation of results using different methods is recommended, as is the seeking of expert advice for major projects.

A simple example

Steel pipework is required to supply a natural gas appliance of 175 kW net heat input. The system operating pressure is 21 mbar. Pipe length from meter to appliance is 45 m. What diameter of pipe will be needed?

We will use the PDC to find the smallest steel pipe diameter that will give a pressure drop no greater than 1 mbar from the meter outlet to the appliance connection.

- Load the PDC and click **Clear All**
- Select **Gas Type** as NG
- Enter **OP** as 21
- Enter **Leg name** as A (or any other name you want)
- Select **Upstream type** as Meter
- Select **Appliance Leg?** as Yes
- Select **Pipe material** as Steel
- Enter **Length** as 45
- Leave **Fittings** blank (for simplicity we ignore fittings in this example)
- Enter **Gas rate** as 18.4 (this is 175 kW divided by the conversion factor 9.5 to obtain the gas rate in m³ / h). You could also enter this as =175/9.5 where the equals sign at the start lets Excel know you want it to evaluate the expression.

We now enter trial diameters, starting with the smallest we think may do the job and working up in size until we get a pressure loss of 1 mbar or lower.

Start by entering 32 into **Diameter** and click **Calculate**; the pressure loss (ΔP_{TOTAL}) comes up as over 6 mbar.

Change Diameter to 40 and click Calculate again; ΔP_{TOTAL} is still well over 1 mbar.

Try 50; the pressure loss falls under 1 mbar.

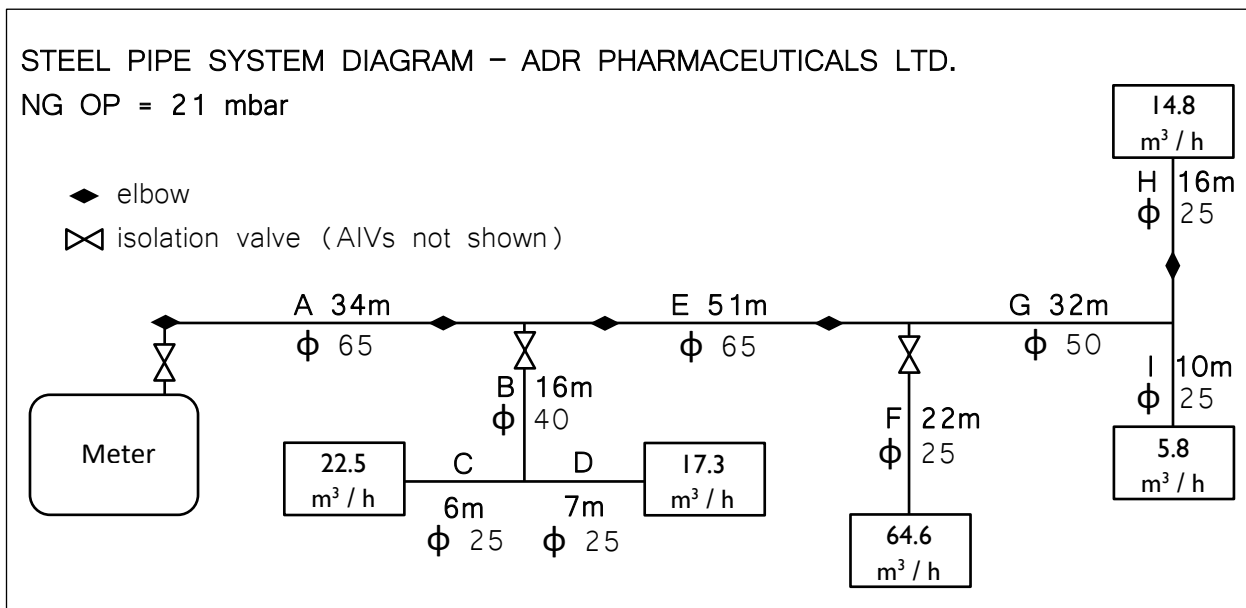
50 mm steel is therefore the smallest size of steel that will work.

The system diagram

In any complex pipe sizing problem it is essential to start with a good diagram. To make effective use of the PDC the diagram should show:

- Fuel gas type
- Operating pressure (OP) in mbar
- All pipe legs (sections between meters, tees, reducers and appliances)
- Pipe leg lengths in metres
- Pipe diameters in millimetres (estimated or actual)
- Pipe fittings (tees, elbows, bends and valves)
- Gas rates of all appliances (preferably in cubic metres per hour)

The diagram below shows a proposed system (including estimate diameters).

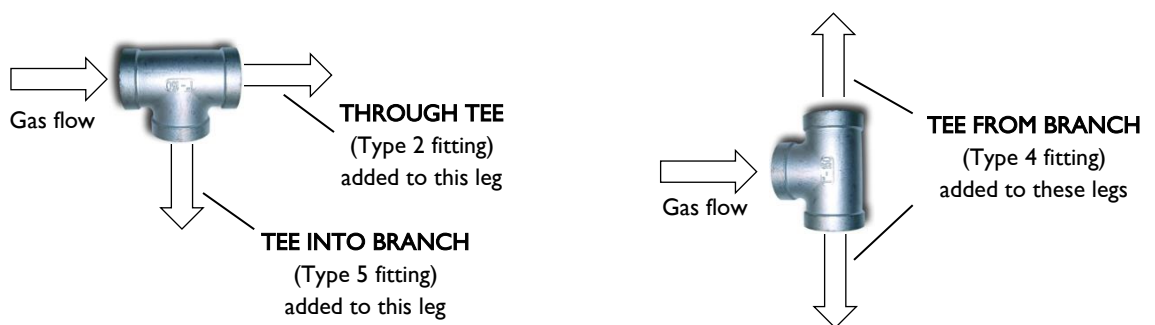


We will use this system as a worked example.

Entering the system details into the PDC

Click **Clear All** to ensure no previous calculations remain. Select **Gas type** as NG (natural gas) and enter **OP** (operating pressure in mbar) as 21. Enter **Leg name** for each leg in order of gas flow (A, B, C, D, E, ...). The first leg name is lilac-shaded to indicate that it connects to the pressure source. *Note: whenever entering L as a leg name, check that Excel does not auto-complete the cell with the text “Leg name”!*

Select the **Upstream type** for each leg in turn. The PDC follows the conventions of IGEM/UP/2 in distinguishing between three configurations of tee:



Upstream types for each leg in the example diagram are:

- A Meter
- B Tee into branch
- C, D Tee from branch
- E Through tee
- F Tee into branch
- G Through tee
- H, I Tee from branch

Note that H and I aren't actually from a branch – they're from the main run – but their configuration is obviously the same as the tee connecting legs C and D.

Enter the **Upstream leg name** of each leg so the PDC knows how the system is connected. The first leg is always set to OP, i.e. the available incoming pressure to the system or section.

In the Upstream leg name of leg B, type a capital letter A. Always type Upstream leg name so it exactly matches the actual name. Press the down arrow key to move to leg C. Leg C gets its gas from leg B, so type B and press the down arrow key. Leg D also gets its gas from leg B, so enter B again and press the down arrow key. Continue until all legs have been connected correctly.

Select **Appliance leg?** as Yes for legs C, D, F, H and I. Certain cells are then highlighted in blue because these values have special significance for appliances.

*Note: the **Isolated** option in the drop-down list allows you to temporarily remove an appliance from calculations. To reinstate the appliance select Yes from the list.*

Select the **Pipe material** of each leg. In this example all pipe legs are steel. You can use cut-and-paste to speed up data entry. Select leg A as Steel, then press CTRL-C to copy. Select cells E9 to E16 and press CTRL-V to paste Steel into all the other legs.

*Note: choosing Pipe material as **Other** causes the PDC to use a very high friction factor which should cover any pipe material. This can be useful for modelling pipework in poor condition, e.g. old or internally-rusted pipework.*

Enter the **Length** of each leg in metres. *Note: only enter numerical data, not the unit of measurement such as “m” for metres etc.*

We will skip entering details of fittings for the moment.

Enter the **Gas rate** (in m³ / h) for all pipe legs which connect directly onto appliances, i.e. legs C, D, F, H and I.

To find the gas rates through all other legs click the **Gas Rates** button.

Note: remember to click the Gas Rates button again if you alter the gas rate of any appliance or if you change the isolated status of an appliance.

Enter the estimate **Diameter** (internal pipe diameter in millimetres) of each leg. Note that the system hasn't yet been pipe sized properly and the diameters shown on the diagram are just guesses.

The PDC now has enough information to calculate pressure losses in the system.

The trial-and-error method

Click the **Calculate** button.

We immediately get warning of high gas speed followed by a Pressure Loss Error on leg F. This means that working pressure has fallen to zero because the diameters are far too small (as you may have suspected). We will now use the PDC to find the correct diameters.

Click OK to clear the error messages and change the diameter of leg A to 80 mm. Click Calculate. This has improved things a little but the PDC is still giving an error. Changing A to 100 mm further improves the **Pressure loss (mbar)** across leg A but the downstream legs are still far too small.

Try changing leg B to 65 mm, C and D to 50 mm, E to 100 mm, F to 65 mm, G to 65 mm, and H and I to 40 mm and re-calculate. The situation has improved so that there is no error but pressure losses to appliances are still more than 1 mbar (this is shown in the ΔP_{TOTAL} column).

We see that the combined loss of the main run legs A and E is over 1 mbar. We therefore make the decision to increase leg A to 125 mm. Appliances C and D now have a drop just below 1 mbar but remember we are yet to add fittings.

Changing E to 125 mm, F to 80 mm and G to 100 mm brings the pressure loss to appliances F and I to under a millibar but appliance H is still over. Changing H to 50 mm corrects this.

This example gives a good idea of the trial-and-error method that can be employed using the PDC. The better the initial guesses, the easier the process.

Adding fittings

The PDC treats fittings as additional pipe lengths calculated using an equation derived from IGEM/UP/2 Table 24. The PDC automatically adds additional length for the following:

- Meter outlet valve (MOV)
- Tees (all configurations)
- Appliance isolation valves
- Reducers
- Isolation valves for branches ≥ 50 mm diameter (NG) or ≥ 30 mm (LPG)

The \emptyset column indicates the largest connection diameter of tees and reducers. According to BS 6891 the additional length for tees that change the direction of gas flow (i.e. into and out of branches) must be based on the largest connection diameter of the tee. The PDC will determine \emptyset automatically except where there is a tee or reducer upstream of the first leg (this may happen if a section of a larger system is being modelled; if so, the PDC will request that you enter \emptyset manually for the first leg).

In this example we only need to manually add elbows. (Branches B and F are now sized at 50 mm or more so the PDC will automatically add a branch isolation valve to both).

- Enter 2 x 90° elbows (Type 3 fittings) to A, 2 to E, and 1 to H

Clicking Calculate shows that appliance C now has a pressure loss slightly over 1 mbar. Sometimes a pressure loss may exceed the permitted limit by an amount smaller than uncertainties in measurements or in the pipe sizing calculations themselves. In such cases a decision may be made to accept the pipe sizes as they are.

Finding the “worst-case” appliance pressures

To see worst-case appliance inlet working pressures, change OP to the lowest available pressure and re-calculate. For example, on a standard natural gas supply of 21 mbar, the tolerance is ± 2 mbar. In this case we would set OP to 19 mbar and re-calculate.

Additional functions of the PDC

Clear Row

To completely clear a row of data, select any cell in the row and click **Clear Row**.

Clear Calcs

Sometimes it is convenient to be able to clear only the PDC's calculations, leaving the user-entered data untouched. To do this, click **Clear Calcs**.

Insert Row

Occasionally it is convenient to split a pipe leg in two or add a new leg; for example, if we decide to insert a reducer or a tee and branch in the middle of an existing leg. First click any selectable cell on the row immediately below the leg you wish to split. Click **Insert Row**. A new blank row appears. You will have to amend any affected Upstream type, Upstream leg name, Length etc. accordingly.

Remove Row

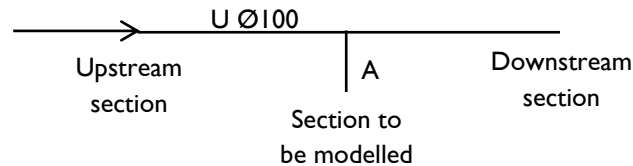
To remove a leg, click on any selectable cell in the row and click **Remove Row**. You will have to amend any affected Upstream leg name accordingly.

Show IV

The PDC will calculate the installation volume of the system (with 10 % added for fittings) when you click **Show IV**.

Pipe sizing a section of a larger system

In some cases we only want to model part of a system. In the example below we wish to model the section from branch A onwards:



Set OP to the available working pressure at the end of leg U. Set the Upstream type of leg A as Tee into branch. Enter \varnothing manually as 100.

The accuracy and limitations of pipe sizing calculations

Using IGEM/UP/2 Table 23 to find the size of steel required to carry 13 m³ / h over 15 m with a 1 mbar drop yields 32 mm. When we put this diameter, length and load into the PDC it predicts a pressure loss slightly over 1 mbar.

One reason for this is that the actual internal diameter of a standard steel pipe is not the same as its nominal bore. Both IGEM and British Standards take this into account when creating pipe sizing tables.

If we reverse-engineer Table 4 of IGE/UP/1 (pipe installation volumes) using the formula $d = 2000 \sqrt{(IV_{\text{METRE}} \div \pi)}$ we see internal diameters that are sometimes larger and sometimes smaller than the nominal bore. For example, 32 mm nominal bore steel works out as: $2000 \sqrt{(0.0011 \div 3.142)} = 37.4$ mm internal diameter.

This is confirmed when we look at Table A.2 in the domestic pipework standard BS 6891 which informs us that 35.6 mm has been used as the internal diameter of 32 mm nominal bore steel pipe.

Changing the diameter from 32 mm to either 37.4 mm or 35.6 mm in the spreadsheet causes the expected loss fall to below 1 mbar, agreeing with Table 23.

In cases of marginal failure (or success) it may be worth obtaining more information about internal diameter from the pipe manufacturer since this is by far the most significant factor in estimating pressure loss.

PDC Quick Reference Guide

Enter system name, section name, and designer name here

Select NG (natural gas) or LPG (propane)

Enter Operating Pressure in mbar

Click to calculate all gas rates in non-appliance pipe legs

Click to calculate all pressure losses in the system

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A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	
1																
2	System				Gas type					Clear All	Show IV	Insert Row				
3	Section				OP					Clear Calcs	Gas Rates	Remove Row				
4	Designer									Clear Row				Calculate		
5																
6	Leg name	Upstream type	Upstream leg name	Appliance leg?	Pipe material	Length (m)	Fittings				Gas rate (m ³ /h)	Diameter (mm)	Pressure loss (mbar)	P _{OUT} (mbar)	ΔP _{TOTAL} (mbar)	Leg name
7							Type 1	Type 2	Type 3	∅ (mm)						
8			OP													
9																
10																

Enter the number of fittings of each type:

Type 1: 45° bend, 90° bend, bush & socket (one size change)

Type 2: through tee, 90° bend, full bore valve, union, adapter, flange joint

Type 3: 90° elbow, bush & socket (more than one size change)

∅: diameter of upstream connection in mm (only needed if reducer or tee to first leg)

Choose: Steel, PE, Copper or Other

Select Yes if this leg connects directly onto an appliance.

Enter the name of the leg immediately upstream of this one

Choose: Meter, Through tee, Tee into branch, Tee from branch, Reducer, Expander, or Other

Give each pipe leg a unique name (e.g. A, B, C, D, etc.)

Total pressure loss from the start of the system to the end of this leg

Pressure at the outlet of this leg

Pressure loss across this leg