COMMERCIAL GAS PIPE SIZING

PART 2 – Using the Pressure Drop Calculator (PDC)

Contents

Course information

These are the user instructions for the **Pressure Drop Calculator (PDC)** developed by RAD Training (Midland) Ltd. for their commercial pipe sizing training course.

The course includes the following optional modules:

Part 1 – Pipe sizing by hand

How to use the pipe sizing charts in IGEM/UP/2 in a fully-developed pressure loss allocation method

Part 2 – Pipe sizing using an app

How to use the Pressure Drop Calculator (PDC)

Part 3 – Pipe sizing extensions to a system

How to determine the feasibility of adding new extensions to existing systems

Part 4 – Theory of fluid flow

How to make your own pipe sizing charts: a deeper look at the physics and mathematics of gas flow through pipes

Contact information

For more information about the course and how to obtain a copy of the PDC, please visit www.radmidlands.co.uk or email r-price@btconnect.com

About the PDC (version 6.3)

The PDC calculates steady-state working pressure losses in steel, PE and copper pipework for low pressure, medium pressure and high pressure natural gas (NG) and LPG (propane) systems.

The PDC can:

·   model systems or sections of up to 58 pipe legs
·   automatically handle many types of fitting
·   automatically calculate gas rates
·   give user warnings if gas speed exceeds 20 m / s
·   calculate installation volume (IV) of pipework and fittings
·   handle a gas ring main
·   handle a twin (parallel) pipe leg

The PDC user interface is a spreadsheet which requires Microsoft Excel installed on your PC. 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.

Pressure loss calculations are always approximate. Many real-world variables including pipe condition, nominal diameter vs internal diameter, quality of jointing etc. have a large effect. Use tolerances which overestimate pressure losses. Double-check all entered data. Confirmation of results using different methods is recommended, as is seeking expert advice for major projects.

Do not use the PDC for real-world projects without having first worked through the examples in this manual.

A simple example

What diameter of steel pipe is needed to supply a 175 kW (net) natural gas boiler? System operating pressure is 21 mbar. Pipe length from meter to appliance is 45 m.
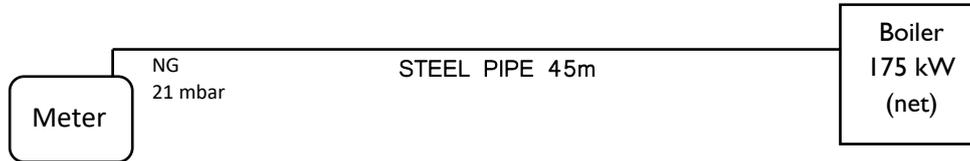
- · Load the PDC and click **Clear All**
- · Select **Gas Type** as NG
- · Enter **OP** as 21
- · Enter **Leg name** as A (or any other name you want)
- · Select **Upstream type** as Meter
- · Select **Appliance Leg?** as Yes
- · Select **Pipe material** as Steel
- · Enter **Length** as 45
- · Leave **Fittings** blank (for simplicity we ignore fittings in this example)
- · Enter **Gas rate** as 18.4 (this is 175 kW divided by the conversion 9.5 to obtain gas rate in m^3 / h). You could also enter this as = 175 / 9.5 where the equals sign 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 1 mbar or lower pressure loss (the maximum allowed).

Start by entering 32 into **Diameter**. Click **Calculate**. Total pressure loss to the end of leg A (**ΔP$_{TOTAL}$**) comes to more than 6 mbar, which is unacceptable:

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)
						Type 1	Type 2	Type 3	Ø (mm)					
A	Meter	OP	Yes	Steel	45					18.42	32	6.12	14.9	6.12

Change Diameter to 40 and click Calculate again. ΔP$_{TOTAL}$ is still over 2 mbar.

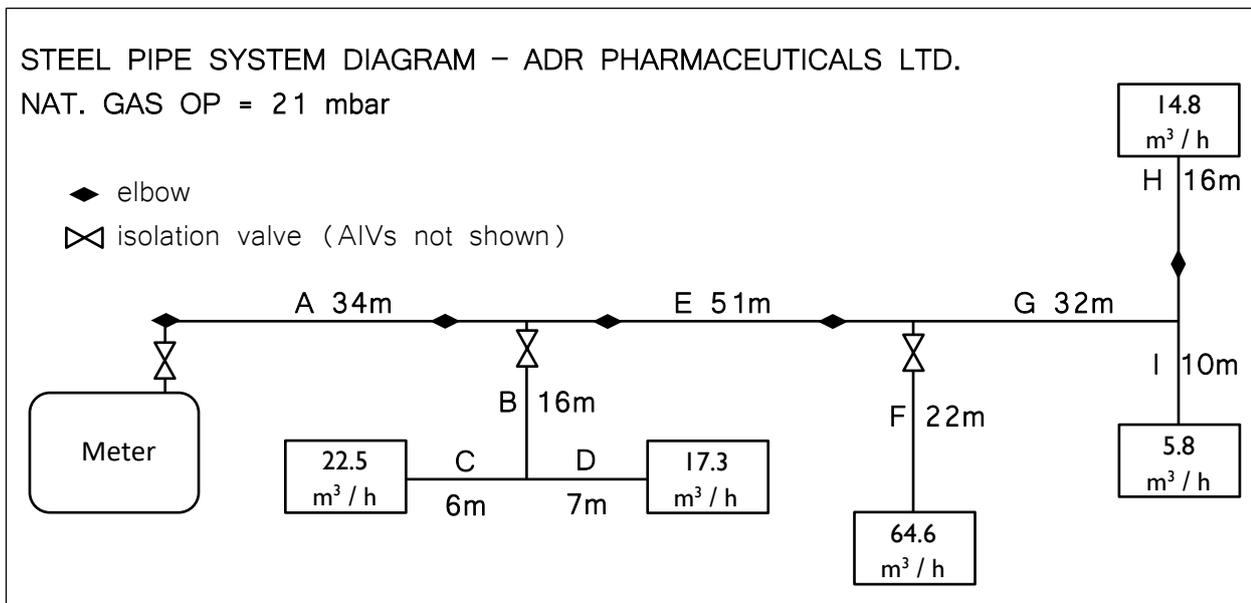Try 50. Pressure loss falls under 1 mbar.

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

The system diagram

In any complex pipe sizing problem it is essential to start with a good diagram. The diagram should show:

· Fuel gas type
· Operating pressure (OP) in mbar
· All pipe legs (pipe sections between meters, tees, reducers and appliances)
· Pipe leg lengths in metres
· 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 which we will use as a worked example.

STEEL PIPE SYSTEM DIAGRAM – ADR PHARMACEUTICALS LTD.
NAT. GAS OP = 21 mbar

◆ elbow
⋈ isolation valve (AIVs not shown)

```
                    A 34m              E 51m              G 32m
   Meter                                                              H 16m  14.8 m³/h
          B 16m                                          I 10m
   22.5 m³/h  C  D  17.3 m³/h          F 22m             5.8 m³/h
          6m     7m                    64.6 m³/h
```

Note: the common node-based method of naming legs (A-B, B-C, B-D etc.) should not be used in the PDC. Instead, simply give each leg a unique name such as A, B, C, Boiler_3 etc. This has the advantage of reducing visual clutter – and needs one fewer letter to describe a system!

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, ensure Excel does not auto-complete the cell with the text 'Leg name'! We recommend turning off auto-complete when using the PDC.*

Select the **Upstream type** for each leg. For legs coming out of tees, we distinguish three configurations:
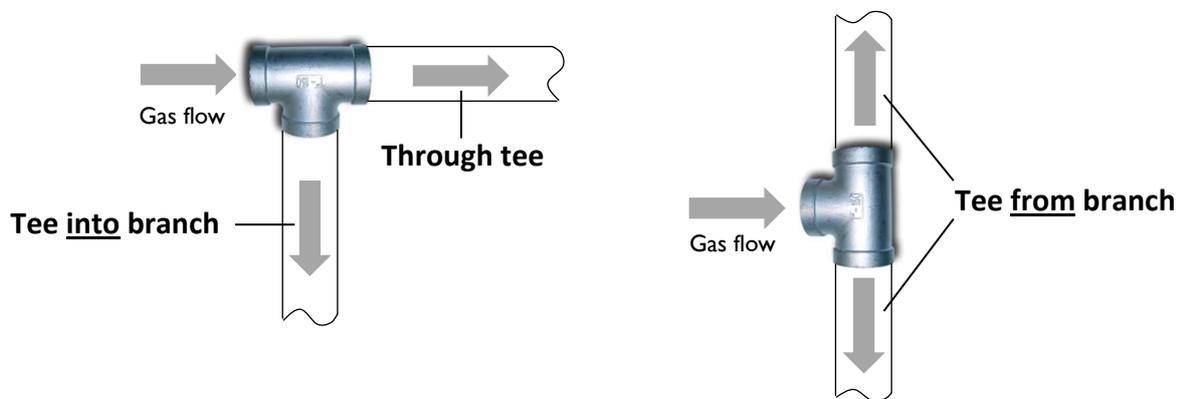
Upstream types in the example are as follows:
- A   Meter
- B   Tee into branch
- C, D   Tee from branch
- E   Through tee
- F   Tee into branch
- G   Through tee
- H, I   Tee from branch

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

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

Leg B gets its gas from leg A. In the Upstream leg name of leg B, type a capital letter **A**. Always type Upstream leg name so it exactly matches the actual leg 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 only. Certain cells are 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. Only appliance legs can be isolated; selecting Isolated for a non-appliance leg will cause an error.*

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 high friction factor. This can be useful for modelling pipework in poor condition, e.g. rusted pipework.*

Enter the **Length** of each leg in metres. *Note: only enter numerical data, <u>not</u> the unit of measurement; i.e. do not enter 'm' for metres after the number.*

We will skip entering fittings for the moment.

Enter the **Gas rate** (in m³ / h) through any legs which connect <u>directly</u> onto appliances, i.e. legs C, D, F, H and I only.

For **Diameter** (<u>internal</u> diameter in millimetres), enter initial guesses as follows:
A=65, B=40, C=25, D=25, E=65, F=25, G=50, H=25, I=25

Note 1: PE pipe is specified by its <u>outside</u> diameter (OD). If SDR (Standard Dimension Ratio) is known, the following formula can be used to find internal diameter (ID):

$$ID = OD - \frac{2 \times OD}{SDR}$$

For example, 63 mm SDR 11 PE pipe, diameter can be entered as = 63 – 2*63/11 which should evaluate to approximately 51.5 mm.

Note 2: copper pipe is specified by its <u>outside</u> diameter. Internal diameter will need to be obtained from the manufacturer.

The trial-and-error method

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

Click the **Calculate** button.

We immediately get warning of high gas speed followed by a Pressure Loss Error on leg F, where PDC informs us that working pressure has fallen to zero. This is because the initial guesses are too small. Click **OK** to clear the errors. We will now use the PDC to find correct diameters.

Change the diameter of:
    A to 100
    B to 65
    C and **D** to 50
    E to 100
    F and **G** to 65
    H and **I** to 40

Re-calculate. The situation has improved but pressure losses are still above 1 mbar (these are shown in the ΔP_{TOTAL} column and are shaded blue for appliance legs).

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

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

Adding fittings

The PDC <u>automatically</u> (and implicitly) adds additional length for the following fittings:

·   Meter outlet valve (MOV) whenever there is a meter
·   Tees (all configurations)
·   Appliance isolation valves
·   Reducers and expanders (except if immediately after the primary meter)
·   Isolation valves for branches ≥ 50 mm diameter (NG) or ≥ 30 mm (LPG)

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 automatically adds branch isolation valves).

·   Enter 2 × 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 calculations. In such cases a decision may be made to accept the pipe sizes as they are.

Note: the Ø column shows the largest connection diameter of tees and reducers. According to IGEM/UP/2, additional length for tees must be based on the diameter of their <u>largest</u> connection. The PDC determines Ø automatically except where there is a tee or reducer upstream of the <u>first</u> leg. This happens when a section of a larger system is being modelled (see page 11). In such situations, the PDC will ask you to enter Ø manually for the first leg.

Finding the 'worst-case' appliance inlet working pressures

To see worst-case appliance inlet working pressures, change OP to the lowest expected available pressure and re-calculate. For example, on a standard UK natural gas supply of 21 mbar, tolerance is ± 2 mbar. Set OP to 19 and re-calculate. *Note: appliance inlet working pressures are shown in the P_{OUT} column of appliance legs.*

Additional functions of the PDC

Clear Row – completely clears all cell data on the selected row

Clear Calcs – clears all PDC calculations, leaving user-entered data untouched

Insert Row – inserts a new blank row above the selected row

Insert Row is used to split a leg in order to add a new branch or insert a reducer etc. For the system in the example, let's say we want to insert a new branch **J** halfway along leg A. Leg A will now become two separate legs which we will call A1 and A2:
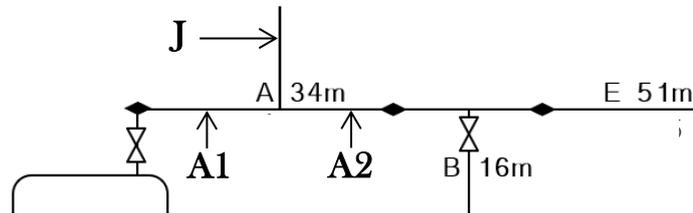
- · Click on any selectable cell in leg B and click **Insert Row**
- · A new blank row appears above leg B. In the new row, enter:
  - – **Leg name**: A2
  - – **Upstream type**: Through tee
  - – **Upstream leg name**: A1
  - – **Pipe material**: Steel
  - – **Length**: 17
  - – **Diameter**: 125
- · For leg A, change **Leg name** to A1 and **Length** to 17
- · For legs B and E, change **Upstream leg name** to A2
- · Below Leg I, enter the details of new branch J (**Upstream leg name**: A1)

Remove Row – removes the selected row, shifting other rows up to fill the gap

Note: any Upstream Row reference to the deleted leg will change to '????' and will have to be amended manually.

Show IV – calculates the installation volume of the pipework (with an additional 10 % to account for fittings)

Modelling very large systems

If a system consists of several discrete sections, each containing banks of appliances, it can be modelled over multiple copies of the PDC: one for the main pipework and one for each appliance bank. For the main system, enter each bank as a single appliance with gas rate equal to the total of the appliances in that bank.
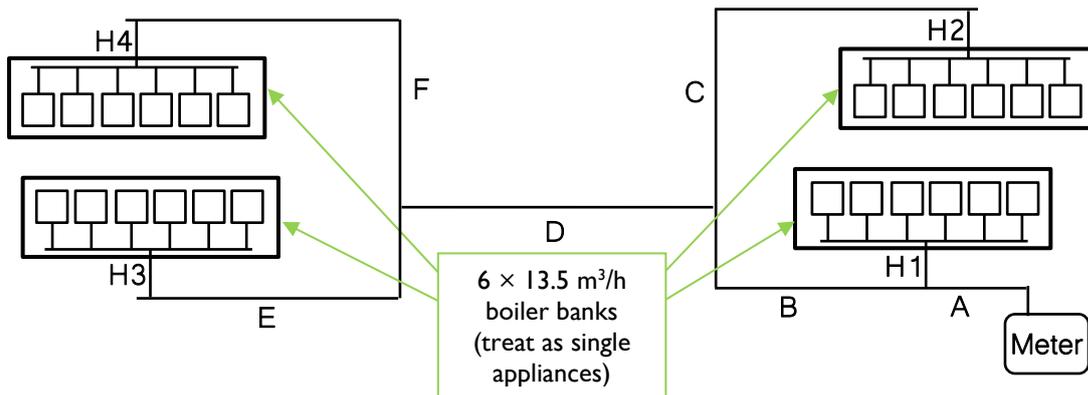
Legs H1, H2, H3 and H4 are entered with **Appliance Leg?** set to Yes and **Gas rate**: 81 (because $6 \times 13.5 = 81$ m^3 / h). **P$_{OUT}$** of legs A, C, E and F should be noted and used as **OP** when the respective banks are modelled.

Modelling sections of a system
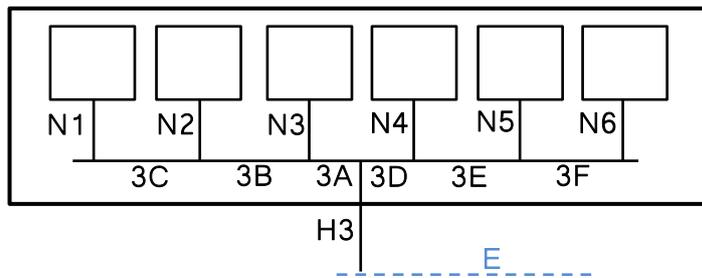
For the boiler bank coming off leg E (for example), create a new PDC. Set **OP** equal to the P$_{OUT}$ of leg E (but do not enter leg E itself into this PDC). Enter legs in order of flow: e.g. H3, 3A, 3B, 3C, 3D, 3E, 3F, N1, N2, N3, N4, N5, N6. Enter **Upstream type** for leg H3 as Tee into branch. Manually enter Ø (upstream diameter) for leg H3 as equal to the diameter of leg E on the main system.

Find pipe sizes that ensure ΔP_{TOTAL} to the appliances do not exceed the allowed value (the maximum allowed drop of the overall installation minus the ΔP_{TOTAL} of leg E).

Gas ring mains

A ring main or 'loop' can be used to improve pressure losses in certain situations. If one section of a system has more than enough pressure, it can be connected to another section lacking in pressure. The PDC can model systems containing a single loop such as the one proposed in the system below:

6 / 7	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)
							Type 1	Type 2	Type 3	Ø (mm)					
8	A	Meter	OP		Steel	11			1		160.00	65	2.80	97.2	2.80
9	B	Through tee	A		Steel	14					40.00	65	0.24	97.0	3.04
10	C	Tee into branch	A		Steel	18				65	120.00	65	2.93	94.3	5.73
11	D	Through tee	C		Steel	24			1		80.00	50	5.69	88.6	11.42
12	E	Through tee	D		Steel	26			1		40.00	50	1.64	86.9	13.05
13	H1	Tee into branch	B	Yes	Steel	2				65	40.00	50	0.63	96.3	3.66
14	H2	Tee into branch	C	Yes	Steel	2				65	40.00	50	0.63	93.6	6.36
15	H3	Tee into branch	D	Yes	Steel	2				50	40.00	50	0.47	88.1	11.89
16	H4	Tee into branch	E	Yes	Steel	2				50	40.00	50	0.47	86.5	13.52

Pipework standards allow pipework of operating pressure above 25 mbar to lose 10 %. Here, OP = 100 mbar so the allowed loss is 10 mbar. Pressure losses at appliances H3 and H4 are more than the limit. Would a loop between legs B and E remedy this situation? Enter the loop leg details as follows:

6 / 7	Leg name	Upstream type	Upstream leg name	Appliance leg?	Pipe material	Length (m)	Fittings				Gas rate (m^3/h)	Diameter (mm)
							Type 1	Type 2	Type 3	Ø (mm)		
17	F	Loop	B,E		Steel	30			1			50

Click **Calculate**.

Pressure drops to H1, H2, H3 and H4 change to 4.16, 5.00, 6.86 and 6.92 mbar respectively. This confirms that a 50 mm diameter loop will bring pressure losses to an acceptable level for all appliances.

We can also see the outcome of fitting a smaller loop leg: changing leg F to 40 mm gives pressure drops of 4.01, 5.31, 7.94 and 8.21 mbar, which would still be acceptable. A further reduction to 32 mm gives pressure drops approaching 10 mbar so the recommended diameter of the loop would be 40 mm.

Note 1: multiple alternative loops can be entered into the PDC but only one can be calculated at any time. Temporarily isolate alternative loops by selecting Isolated in the **Appliance Leg?** *column. To take a loop out of isolation, select No in the Appliance Leg? column. Only the first un-isolated loop is calculated.*

Note 2: a loop always connects the <u>outlets</u> of two legs. Loops cannot connect to appliance legs or 'dead' legs with no downstream appliances.

Note 3: in certain highly-unbalanced situations, when gas flow through the loop has reached the full gas rate of downstream appliances, there is still pressure available. This will cause gas flow to reverse direction in one or more legs. As an example, try changing the loop diameter to 100 mm in the above example. The PDC alerts the user that gas flow will reverse through leg E and that pressure losses upstream of the loop (e.g. in leg B) may be greater than those indicated. The PDC does not at present model this situation. Using a smaller diameter loop will prevent this, although it is not in itself indicative of any problem with the system.

*Note 4: a loop leg must stay the same diameter throughout its length.*

Note 5: the **Gas rates** *button does not take into account the effect of loop legs.*

Twin pipe systems

In the system shown below, pressure loss is unacceptable at 1.7 mbar. Unfortunately, replacement pipework larger than 50 mm would incur the additional expense of welding. Would a twin pipe system correct the problem?
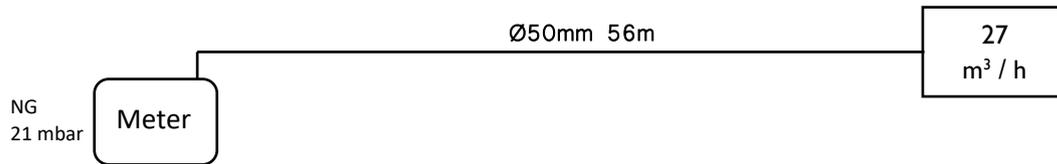
The twin pipe configuration will be:
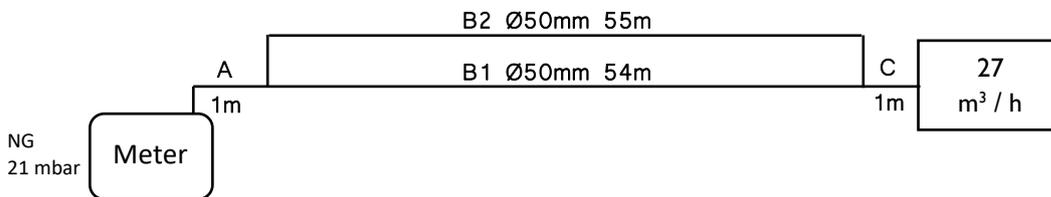
This is modelled in the PDC as:

Leg name	Upstream type	Upstream leg name	Appliance leg?	Pipe material	Length (m)	Fittings				Gas rate (m³ / h)	Diameter (mm)	Pressure loss (mbar)	P$_{OUT}$ (mbar)	ΔP$_{TOTAL}$ (mbar)
						Type 1	Type 2	Type 3	Ø (mm)					
A	Meter	OP		Steel	1			1			50			
B1	Through tee	A		Steel	54						50			
B2	Loop	A,B1		Steel	55			2			50			
C	Through tee	B1	Yes	Steel	1					27.00	50			

Note: loop leg B2 connects the <u>end of leg A</u> to the <u>end of leg B1</u>. You cannot connect a loop to an appliance leg such as leg C.

Clicking **Calculate** reveals ΔP$_{TOTAL}$ falls to 0.79 mbar. Running a twin pipe will therefore solve the pressure loss problem.

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 (with **Gas type** NG and **OP** 21) 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. 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 $d = 2000 \sqrt{(IV_{1METRE} \div \pi)}$, 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 was used as the internal diameter of 32 mm nominal bore steel pipe when the table was calculated.

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. 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 gas rates in non-appliance and non-loop pipe legs

Click to calculate all pressure losses in the system

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1								Clear All	Show IV	Insert Row	Pressure Drop Calculator © 2020 RAD Training (Midland) Ltd.					
2	System	DAR AEROSPACE LTD.			Gas type	NG		Clear Calcs	Gas Rates	Remove Row						
3	Section	HANGARS & LABS			OP	20	mbar	Clear Row						Calculate		
4	Designer	E. MUSK														
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	Ø (mm)						
8	A	Meter	OP		Steel	64			1		181.68	150	0.32	19.7	0.32	A
9	B	Through tee	A		Steel	52			2		67.05	150	0.05	19.6	0.37	B
10	C	Through tee	B		Steel	21			2		67.05	150	0.03	19.6	0.40	C
11	D	Reducer	C		Steel	47		1		150	67.05	100	0.28	19.3	0.68	D
12	H1	Tee into branch	D	Yes	Steel	7				100	12.63	50	0.15	19.2	0.83	H1
13	H2	Through tee	D		Steel	17				100	54.42	100	0.07	19.3	0.75	H2
14	H3	Tee into branch	H2	Yes	Steel	7				100	21.68	50	0.39	18.9	1.14	H3

Give each leg a unique name; e.g. A, B, C, etc.

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

Select Yes if this leg connects <u>directly</u> onto an appliance. To temporarily isolate an appliance or loop, select Isolated.

Name of the leg immediately upstream. For loop legs, enter the name of the two legs connected by the loop, separated by a comma; e.g. B,F

Steel, PE, Copper or Other

Fittings

Type 1: 45° bend, 90° long bend, reducer (1 size change)

Type 2: Through tee, 90° bend, valve, union, adapter, flange

Type 3: 90° elbow, reducer (> 1 size change)

φ: Upstream connection diameter

Pressure loss across this leg

Pressure at the outlet of this leg

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