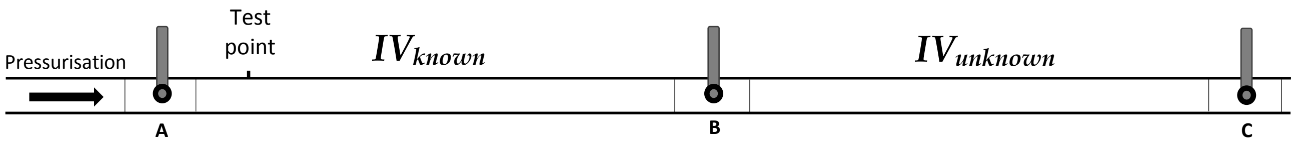
ESTIMATING IV OF AN INACCESSIBLE PIPE SECTION

It is possible to estimate the installation volume (IV) of an inaccessible pipe section using a **pressure change method** if the section can be isolated from a section of known IV and safely depressurised. Consider the following system:



1. Safely attach a pressure gauge to the test point
2. Close valve B
3. Open valve C and **safely** depressurise section BC to atmospheric pressure
4. Open valve A and pressurise section AB to some pressure P_1
5. Close valve A
6. Close valve C
7. Open valve B
8. Record the new pressure P_2

$$IV_{unknown} \approx (P_1 \div P_2 - 1) \times IV_{known} \qquad (1.0)$$

Example

The installation volume of AB is 0.0259 m^3. Its initial pressure was 23.70 mbar and after valve B was opened this dropped to 18.34 mbar. Using equation (1.0):

$$\begin{aligned} IV_{unknown} &\approx (P_1 \div P_2 - 1) \times IV_{known} \\ &= (23.70 \div 18.34 - 1) \times 0.0259 \\ &= 0.00757 \text{ m}^3 \end{aligned}$$

Accuracy

In tightness test and purging calculations it is vital that IV is not underestimated. Adding the GRM of the pressure gauge to P_1 and subtracting the GRM from P_2 should ensure any gauge inaccuracy does not cause underestimation.

For an electronic gauge of GRM = 0.1 mbar, the above example becomes:

$$\begin{aligned} IV_{unknown} &\approx (23.80 \div 18.24 - 1) \times 0.0259 \\ &= 0.00789 \text{ m}^3 \end{aligned}$$

Errors will be greatest when P_1 and P_2 are close in value (i.e. when $IV_{unknown}$ is much smaller than IV_{known}) or when P_2 is close to zero (i.e. when $IV_{unknown}$ is much larger than IV_{known}). The method is most accurate when known and unknown volumes are similar.

It is important that gas temperature does not change significantly between measurement of P_1 and P_2. In practice, inaccessible sections are likely to be underground, where temperatures are different from above ground. If too long is taken between measurement of P_1 and P_2 gas may stabilise at the new temperature and results will be inaccurate.

Derivation

Equation (1.0) was derived from the **ideal gas equation of state**:

$$P\,V = N\,K_B\,T \qquad (2.0)$$

Where P = Absolute pressure, V = Container volume, N = Number of molecules, K_B = Boltzmann constant, T = Absolute temperature

There are initially N_1 gas molecules in section AB. After valve B is opened, N_2 molecules remain. By equation (2.0):

$$(P_1 - P_2)\,IV_{known} = (N_1 - N_2)\,K_B\,T \qquad (2.1)$$

These $(N_1 - N_2)$ molecules enter section BC and increase its pressure from 0 mbar to P_2. Therefore:

$$(P_2 - 0)\,IV_{unknown} = (N_1 - N_2)\,K_B\,T$$

Using equation (2.1):

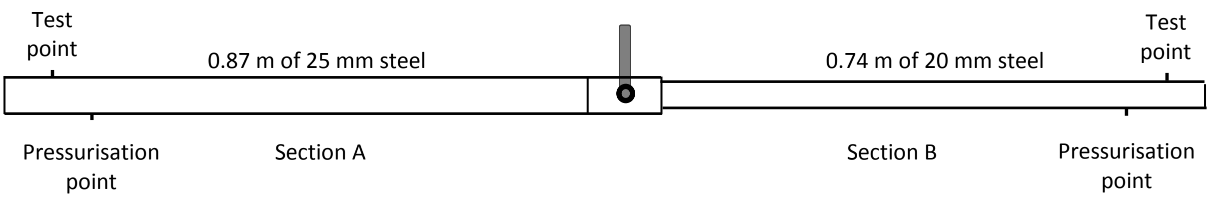
$$(P_2 - 0)\,IV_{unknown} = (P_1 - P_2)\,IV_{known}$$

$$IV_{unknown} = (P_1 - P_2)\,IV_{known} \div P_2$$

$$= (P_1 \div P_2 - 1)\,IV_{known}$$

Testing

The pressure change method was tested using two pipework sections A and B:



Calculated IVs (using IGEM tables): $IV_A = 0.00056\ m^3$, $IV_B = 0.00034\ m^3$.

The section isolation valve was closed and Section B was depressurised to atmospheric pressure (0 mbar). Section A was pressurised with air to pressure P_1. The section isolation valve was opened and the new pressure P_2 was recorded. This process was repeated four times, each time using the pressure remaining in Section A as the new P_1.

P_1 (mbar)	P_2 (mbar)	$P_1 \div P_2 - 1$	Estimate IV_B	Estimate IV_B (GRM-adjusted)
127.2	82.2	0.5474	0.0003066	0.0003083
83.2	53.5	0.5551	0.0003109	0.0003136
54.4	34.7	0.5677	0.0003179	0.0003221
35.7	22.4	0.5937	0.0003325	0.0003390
23.4	14.8	0.5811	0.0003254	0.0003352

The method appears most accurate at lower starting pressures. This may be because there is less temperature change as the gas expands into the new volume. It may also be because elevated pressures expand the pipe volume (or the test hose volume).

At the lowest test pressure, after P_1 and P_2 were GRM-adjusted, the result was within 2% of the calculated IV. At the highest test pressure without adjustment for GRM the result was within 10% of the calculated IV.