Appendix

Information given

Diameter, d=0.03m | Length, L=8 m | Roughness, $\varepsilon/D = 0.00005$ |
T_{in} = 293 K |P_{in} = 300 kPa | P_{atm} = 101 kPa | R=8.314

Information found to be constant:

Gas	Air	Ammonia	Ethylene	Methane	Sulphur dioxide
γ	1.4	1.316	1.2461	1.32	1.26
M	0.029	0.017	0.028	0.016	0.0641
$c = \sqrt{\frac{\gamma RT}{M}}$	342.93	434.25	329.26	448.30	218.82
$\rho = \frac{PM}{RT}$	3.5714	2.0936	3.4483	1.9704	7.8941

Methods to calculate

Choked Conditions

1. Assume that the system is under choked conditions.
2. Guess initial value for f (e.g. = 0.02).
3. Then, solve for Ma_1 since all other variables are ascertained.

$$\frac{\gamma+1}{2}\ln\left[\frac{\left(1+\frac{\gamma-1}{2}Ma_1^{\;2}\right)}{Ma_1^{\;2}\left(1+\frac{\gamma-1}{2}\right)}\right]-\frac{1}{Ma_1^{\;2}}+1+\gamma\frac{fL}{d}=0$$

4. Calculate Re_1.

$$\mathrm{Re}_1=\frac{(\rho Dc)\mathrm{Ma}_1}{\mu}$$

5. Calculate new f using the Haaland Equation.

$$\frac{1}{\sqrt{f}}=-1.8\log_{10}\left[\left(\frac{\varepsilon/D}{3.7}\right)^{1.11}+\frac{6.9}{\mathrm{Re}_1}\right]$$

6. Iterate steps 1 – 4 until the new f is closed enough with the old f set. This process is being done by using the 'loop' function in matlab with the codes and results attached.
7. Find P_2 with the equation:

$$\frac{P_{2,choked}}{P_1}=Ma_1\sqrt{\frac{1+\frac{\gamma-1}{2}Ma_1^{\;2}}{1+\frac{\gamma-1}{2}}}$$

And check to see if $P_{2,choked} > P_{atm}$ (100kPa). If $P_{2,choked} < P_{atm}$, the choked assumption is wrong and move on to solve the unchoked conditions (Step 9).

8. If $P_{2,choked} > P_{atm}$, calculate the mass flow rate. $Q_m=\rho VA=AMa_1P_1\sqrt{\frac{\gamma M}{RT_1}}=AMa_2P_2\sqrt{\frac{\gamma M}{RT_2}}$

Unchoked Conditions

9. Guess initial value of Ma_1 (e.g. = 0.3).
10. Calculate Re_1 and f as per steps 4 & 5 respectively.
11. Solve for Ma_2.

$$\frac{\gamma+1}{2}\ln\left[\frac{Ma_2^{\,2}\left(1+\frac{\gamma-1}{2}Ma_1^{\,2}\right)}{Ma_1^{\,2}\left(1+\frac{\gamma-1}{2}Ma_2^{\,2}\right)}\right]-\frac{1}{Ma_1^{\,2}}+\frac{1}{Ma_2^{\,2}}+\gamma\frac{fL}{d}=0$$

12. Check to see if P_2 is correct (= P_{atm}, 100kPa)

$$\frac{P_2}{P_1}=\frac{Ma_1}{Ma_2}\sqrt{\frac{1+\frac{\gamma-1}{2}Ma_1^{\,2}}{1+\frac{\gamma-1}{2}Ma_2^{\,2}}}$$

13. If P_2 is incorrect, guess a new value for Ma_1 and repeat steps 9 – 12 until $P_2 = P_{atm}$. Once correct, stop the iterations.
14. Calculate the mass flow rate.

$$Q_m=\rho VA=AMa_1P_1\sqrt{\frac{\gamma M}{RT_1}}=AMa_2P_2\sqrt{\frac{\gamma M}{RT_2}}$$

See Matlab code below: