# Chapter 2

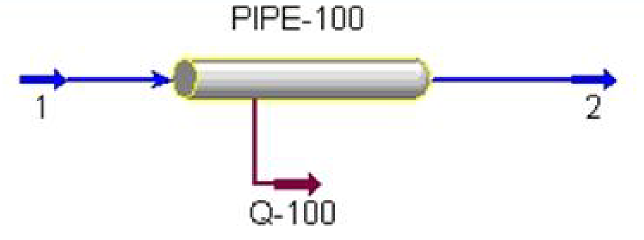
## 2.1 Pressure drop through a smooth pipe

Water is flowing in a 15 m horizontal smooth pipe at 8 $m^3$/h and 35 $^oC$. The density of water is 998 kg/$m^3$ and the viscosity of water is 0.8 cP. The pipe is Schedule 40, 1 inch nominal diameter (2.66 cm ID). Water inlet pressure is 2 atm. Calculate pressure drop.

**Unisim Solution**

Using Hysys: fluid package: ASME steam

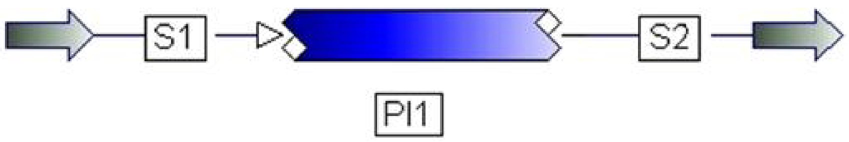
The pressure drop = 73.96 kPa




| Streams | | | |
|---|---|---|---|
| | | 1 | 2 |
| Vapour Fraction | | 0.0000 | 0.0000 |
| Temperature | F | 95.00 | 95.00 |
| Pressure | psia | 29.39 | 18.67 |
| Molar Flow | lbmole/hr | 977.0 | 977.0 |
| Mass Flow | lb/hr | 1.760e+004 | 1.760e+004 |

**Fig. 2.1** Pressure drop through pipe, solved with Unisim

**PRO/II solution** (Fig. 2.2)



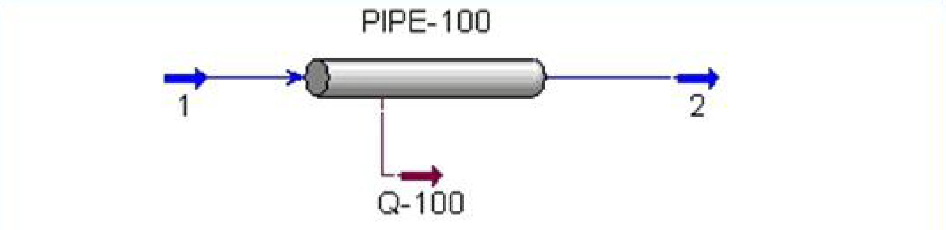

| Stream Name<br>Stream Description | | S1 | S2 |
|---|---|---|---|
| Phase | | Water | Water |
| Temperature<br>Pressure | C<br>KPA | 35.000<br>202.650 | 35.023<br>95.919 |
| Flowrate | KG-MOL/HR | 443.630 | 443.630 |
| Composition<br>WATER | | 1.000 | 1.000 |

**Fig. 2.2** Pressure drop through smooth pipe solved by PRO/II

### 2.2 Pressure drop in a horizontal pipe

Calculate the pressure drop of water through a smooth horizontal pipe 50 m long. The inlet pressure is 100 kPa, the average fluid velocity is 1 m/s. Pipe diameter is 10 cm, pipe relative roughness is zero. Fluid density is 1 kg/L, and viscosity is 1 cP.

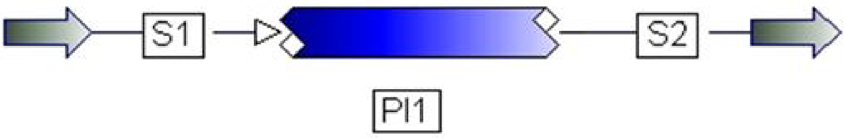
**Unisim Solution** (Fig. 2.3)
The volumetric flow rate: cross sectional area * velocity = 36 $m^3$/h
Pressure drop = 6.47 kPa
Assume outer diameter as 11 cm, the outer has no effect on pressure drop.




| Streams | | | |
|---|---|---|---|
| | | 1 | 2 |
| Vapour Fraction | | 0.0000 | 0.0000 |
| Temperature | F | 95.00 | 95.00 |
| Pressure | psia | 14.50 | 13.57 |
| Molar Flow | lbmole/hr | 4397 | 4397 |
| Mass Flow | lb/hr | 7.921e+004 | 7.921e+004 |
| Actual Volume Flow | barrel/day | 5457 | 5457 |

**Fig. 2.3** Pressure drop through 50 m smooth pipe

**PRO/II solution** (Fig. 2.4)



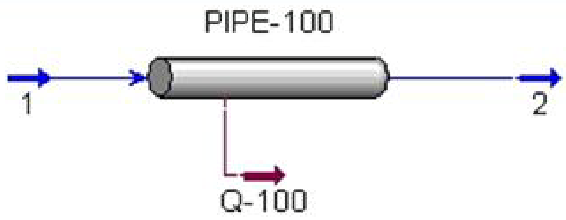

| Stream Name<br>Stream Description | | S1 | S2 |
|---|---|---|---|
| Phase | | Water | Water |
| Temperature<br>Pressure | C<br>KPA | 25.000<br>100.000 | 25.002<br>93.216 |
| Flowrate | KG-MOL/HR | 1996.333 | 1996.333 |
| Composition<br>WATER | | <br>1.000 | <br>1.000 |

**Fig. 2.4** Pressure drop through 50 m smooth pipe solved with PRO/II

## 2.3 Pressure drop in a pipe with elevation

Calculate the pressure drop of water through a pipe 50 m long (relative roughness is 0.01 m/m). The inlet pressure is 100 kPa, the average fluid velocity is 1 m/s. Pipe diameter is 10 cm. Fluid density is 1 kg/L, and viscosity is 1 cP. The water is discharged at an elevation 2 m higher than water entrance.

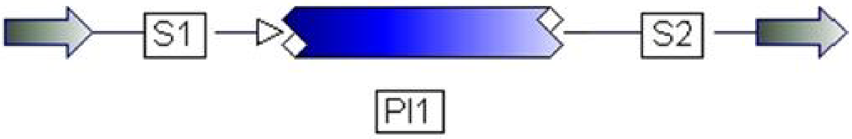
**Unisim solution (**Fig. 2.3)
The problem is the same as that of Problem 2.4.2 except the change in elevation, this is to show that 2 m of change in elevation makes big difference in pressure drop (25.96 kPa)




| Streams | | | |
|---|---|---|---|
| | | 1 | 2 |
| Vapour Fraction | | 0.0000 | 0.0000 |
| Temperature | F | 95.00 | 95.00 |
| Pressure | psia | 14.50 | 13.57 |
| Molar Flow | lbmole/hr | 4397 | 4397 |
| Mass Flow | lb/hr | 7.921e+004 | 7.921e+004 |
| Actual Volume Flow | barrel/day | 5457 | 5457 |

**Fig. 2.5** Pressure drop through 2 m elevated pipe, solved with Unisim

**PRO/II solution**



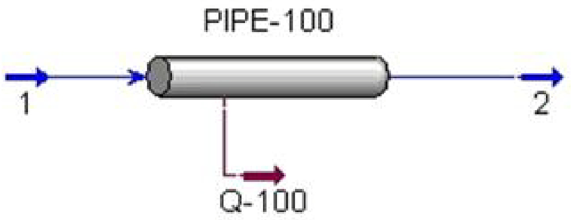

| Stream Name<br>Stream Description | | S1 | S2 |
|---|---|---|---|
| Phase | | Water | Water |
| Temperature<br>Pressure | C<br>KPA | 25.000<br>100.000 | 25.003<br>64.917 |
| Flowrate | KG-MOL/HR | 1996.333 | 1996.333 |
| Composition<br>WATER | | 1.000 | 1.000 |

**Fig. 2.6** Pressure drop in a smooth pipe, elevation = 10 m

## 2.4 Pumping of natural gas in a pipeline

Natural gas contains 85 mole% methane and 15 mole% ethane is pumped through a horizontal schedule 40, 6-in-diameter cast-iron pipe at a mass flow rate of 363 kg/hr. If the pressure at the pipe inlet is 3.5 bars and 25 $^{o}$C, the pipe length is 20 km downstream, assume incompressible flow. Calculate the pressure drop across the pipe using Hysys, Aspen Plus and PRO/II.

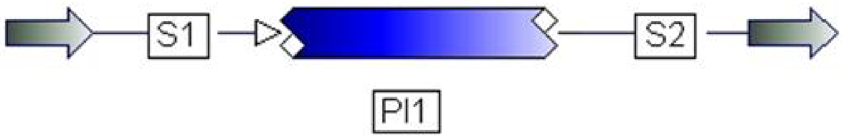
**Hysys simulation** (Fig. 2.7)
Fluid package: Peng Robinson
Pressure drop: 19.23 kPa




| Streams | | | |
|---|---|---|---|
| | | 1 | 2 |
| Vapour Fraction | | 1.0000 | 1.0000 |
| Temperature | F | 77.00 | 95.00 |
| Pressure | psia | 50.76 | 47.97 |
| Molar Flow | lbmole/hr | 44.10 | 44.10 |
| Mass Flow | lb/hr | 800.3 | 800.3 |
| Actual Volume Flow | barrel/day | 2.117e+004 | 2.319e+004 |

**Fig. 2.7** Pressure drop of natural gas through 20 km

**PRO/II simulation** (Fig. 2.18)




| Stream Name<br>Stream Description | | S1 | S2 |
|---|---|---|---|
| Phase | | Vapor | Vapor |
| Temperature<br>Pressure | C<br>KPA | 25.000<br>350.000 | 24.923<br>334.900 |
| Flowrate | KG-MOL/HR | 21.044 | 21.044 |
| Composition<br>METHANE<br>ETHANE | | <br>0.914<br>0.086 | <br>0.914<br>0.086 |

**Fig. 2.8** Pressure drop through 20 km smooth pipe

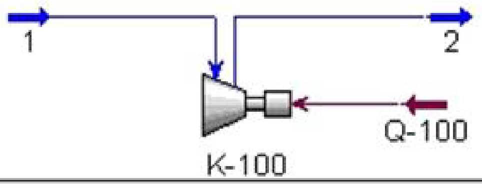
## 2.5 Compression of gas mixture

The mass flow rate of a gas stream 100 kg/h of feed contains 60 wt% methane and 40 % ethane at 20 bar and 35 $^oC$ is being compressed to 30 bar (use PR fluid package). Determine the temperature of the exit stream in degree C.

**Unisim Solution:**

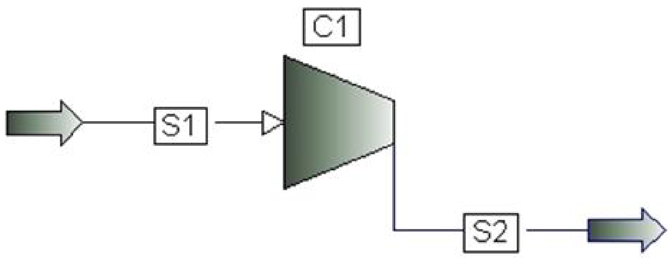
Fluid Package: Peng Robinson

Exit temperature = 70.18




| Streams | | | |
|---|---|---|---|
| | | 1 | 2 |
| Vapour Fraction | | 1.0000 | 1.0000 |
| Temperature | C | 35.00 | 62.89 |
| Pressure | kPa | 2000 | 3000 |
| Molar Flow | kgmole/h | 5.070 | 5.070 |
| Mass Flow | kg/h | 100.0 | 100.0 |
| Actual Volume Flow | m3/h | 6.096 | 4.403 |
| Comp Mole Frac (Methane) | | 0.7376 | 0.7376 |
| Comp Mole Frac (Ethane) | | 0.2624 | 0.2624 |

**Fig. 2.9** Compression of natural gas stream, 100% adiabatic efficiency



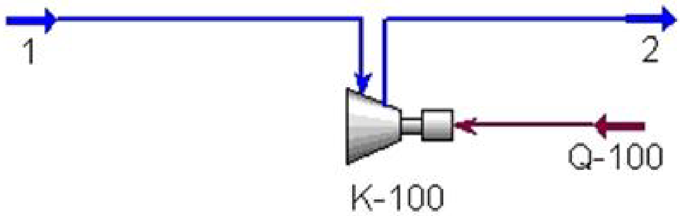

| Stream Name<br>Stream Description | | S1 | S2 |
|---|---|---|---|
| Phase | | Vapor | Vapor |
| Temperature<br>Pressure | C<br>KPA | 35.000<br>2000.000 | 63.052<br>3000.000 |
| Flowrate | KG-MOL/HR | 5.070 | 5.070 |
| Composition<br>METHANE<br>ETHANE | | <br>0.738<br>0.262 | <br>0.738<br>0.262 |

**Fig. 2.10** Compression of natural gas stream, 100% adiabatic efficiency, PRO/II

## 2.6 Compression of Nitrogen

Find the compressor horsepower required to compress 100 kmol/h of nitrogen from 1atm and 25 $^{o}$C to 5 atm.

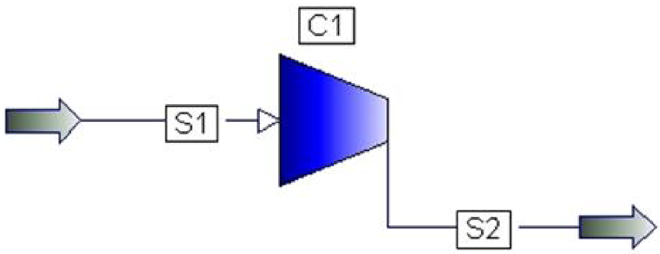
**Hysys solution** (Fig. 2.11)
Fluid package: PR
Compressor horsepower = 187.2 kW




| Streams | | | |
|---|---|---|---|
| | | 1 | 2 |
| Vapour Fraction | | 1.0000 | 1.0000 |
| Temperature | C | 25.00 | 195.9 |
| Pressure | kPa | 101.3 | 506.6 |
| Molar Flow | kgmole/h | 100.0 | 100.0 |
| Mass Flow | kg/h | 2801 | 2801 |
| Actual Volume Flow | m3/h | 2445 | 770.9 |

**Fig. 2.11** Compression of nitrogen gas from 1 to 5 atm.

**PRO/II simulation** (Fig. 2.12)




| Stream Name<br>Stream Description | | S1 | S2 |
|---|---|---|---|
| Phase | | Vapor | Vapor |
| Temperature<br>Pressure | C<br>KPA | 25.000<br>101.325 | 198.266<br>506.625 |
| Flowrate | KG-MOL/HR | 100.000 | 100.000 |
| Composition<br>NITROGEN | | <br>1.000 | <br>1.000 |

**Fig. 2.12** compression of nitrogen gas from 1 to 5 atm, generated with PRO/II

### 2.7 Pumping of pure water

Pure water is fed at a rate of 100 lb/hr to a pump at 250 $^oF$, 44.7 psia. The exit pressure is 1200 psig. Plot the pump adiabatic efficiency versus the energy required?

**Hysys Solution** (Fig. 2.13)
Fluid package: ASME steam
To plot adiabatic efficiency versus energy required, use:
Tools>> Data book>>Insert>>

- Add adiabatic efficiency
- Heat flow

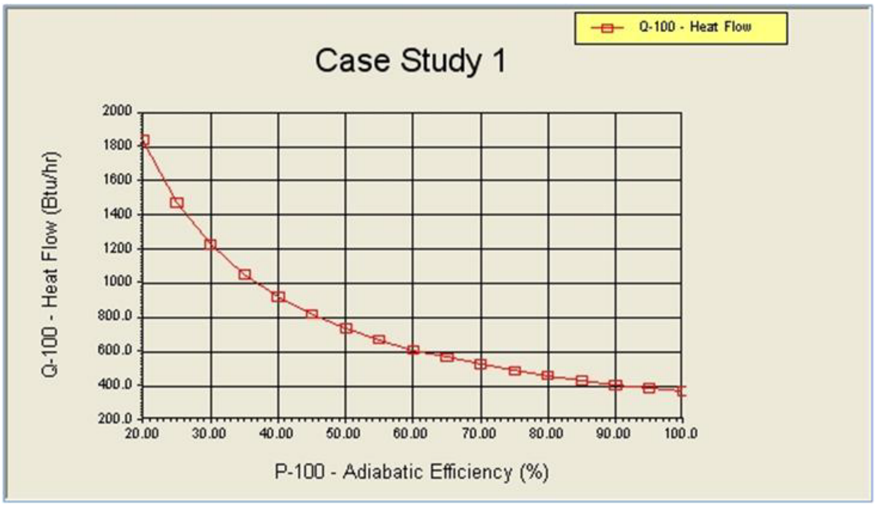
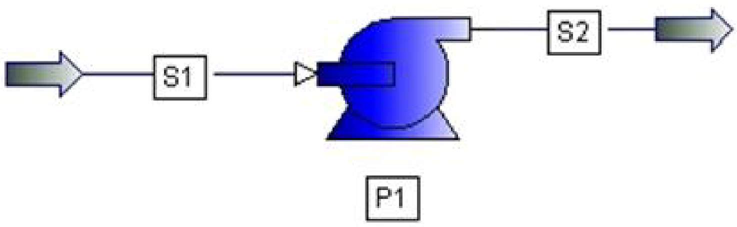



Fig. 2.13 Heat flow versus adiabatic efficiency

**PRO/II simulation** (Fig. 2.14)




| Stream Name<br>Stream Description | | S1 | S2 |
|---|---|---|---|
| Phase | | Water | Water |
| Temperature<br>Pressure | F<br>PSIA | 250.000<br>44.700 | 251.217<br>1200.000 |
| Flowrate | LB-MOL/HR | 5.551 | 5.551 |
| Composition<br>WATER | | 1.000 | 1.000 |

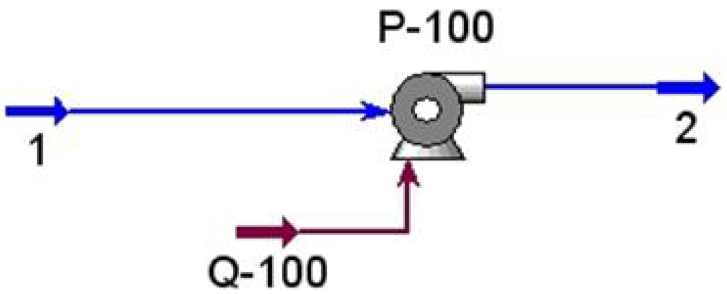
**Fig. 2.14** Pumping of liquid water

### 2.8 Pumping of water to top of building

Calculate the size of the pump required to pump 100 kmol/min of pure water at 1 atm and 25 $^{o}$C to the top of a building 12 m high.

**Hysys Solution** (Fig. 2.15)

The pressure at the exit of the pump is the head pressure + Patm
So the exit pressure is approximately 1.2 atm + 1atm = 2.2 atm




| P-100 | | |
|---|---|---|
| Energy | 1.318e+004 | kJ/h |
| Actual Vol. Flow | 108.4 | m3/h |
| Feed Pressure | 101.3 | kPa |
| Product Pressure | 222.9 | kPa |
| Product Temperature | 25.00 | C |

**Fig. 2.15** Energy required pumping