TMR 4585 Specialization Course UWT

Introduction to Subsea Pipeline Technology

Heat transfer and thermal insulation

by

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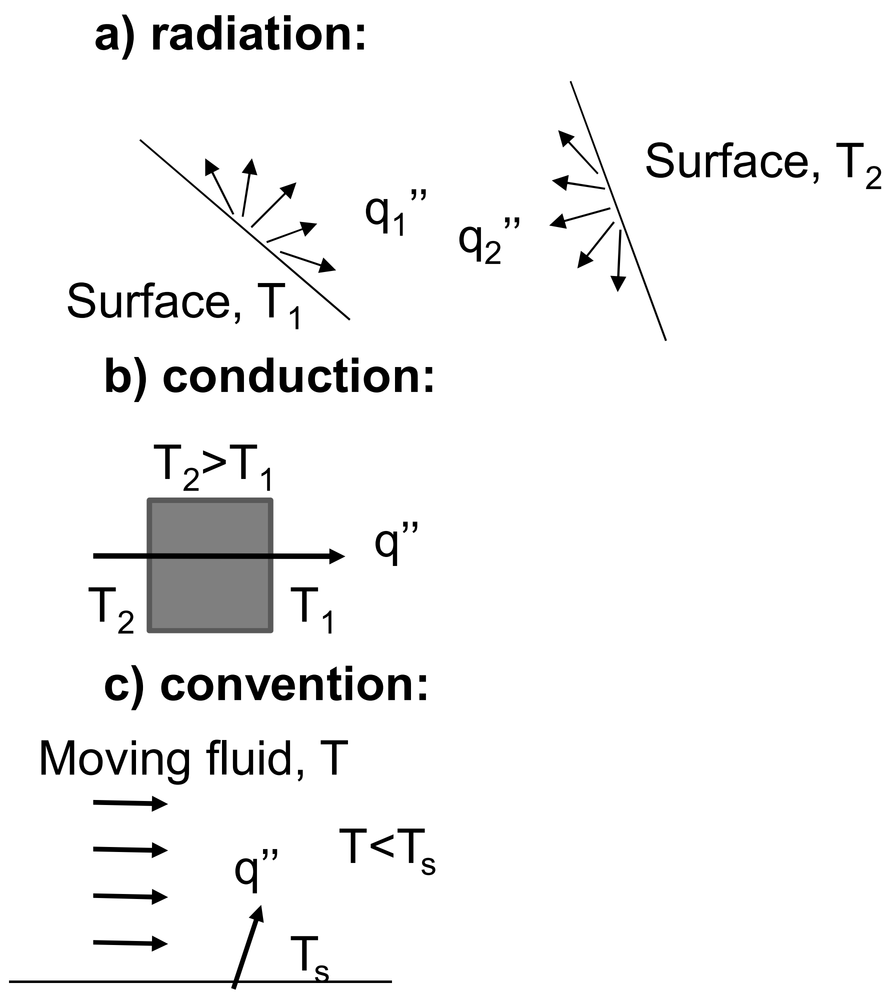
Contents

- **The heat transferr coefficient**
- **Steady state temperature profile**
- **Simplified shut-down simulation**

The heat transferr coefficient

- **Heat is transmitted in three ways:**
  - ➢ By radiation
  - ➢ Conduction
  - ➢ Surface convection:
    - ✓ at the inner pipe wall (well-stream)
    - ✓ At the outer pipe surface



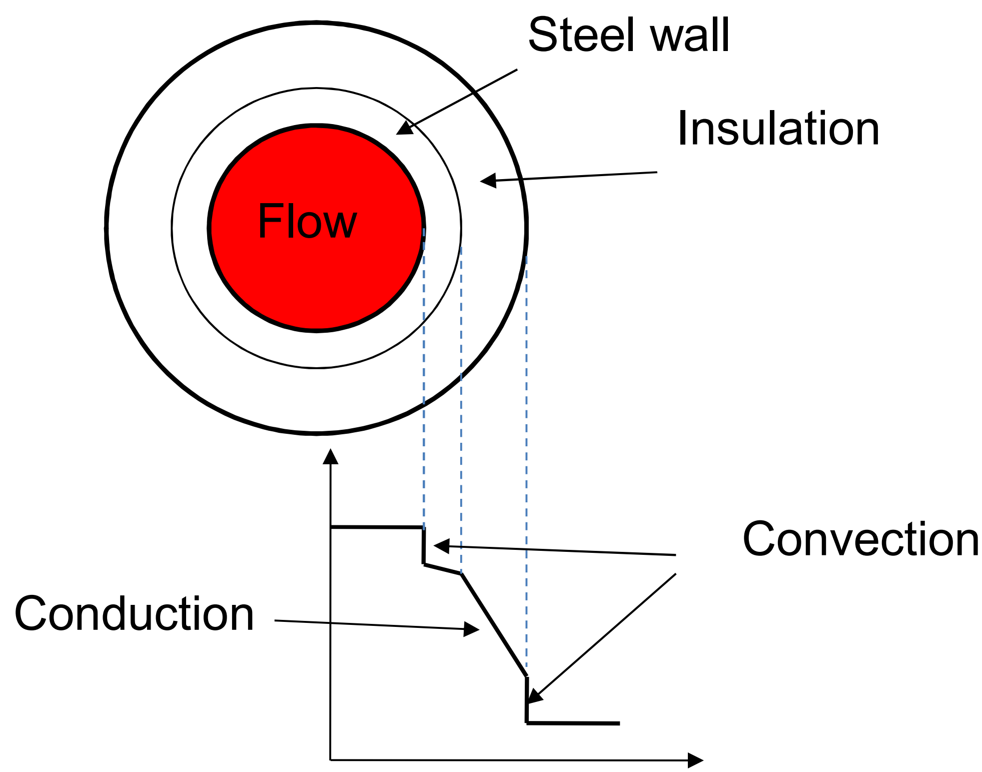
Steady state heat transferr in pipelines

- **Radiation can be neglected here because temperatures are below 200 deg.**

- **Conduction**

- **Surface convection:**
  - at the inner pipe wall (well-stream)
  - At the outer pipe surface

Steady state heat transferr in pipelines



The heat transferr coefficient

- **Multilayered conduction of a pipe cross-section:**

$$Q_r = -2\pi r k \frac{dT}{dr} \qquad Q_r = u 2\pi r_i (T_1 - T_n)$$

- **Referring to inner radius:**

$$u_i = \frac{1}{r_i \sum \frac{\ln(\frac{r_{j+1}}{r_j})}{k_j}}$$

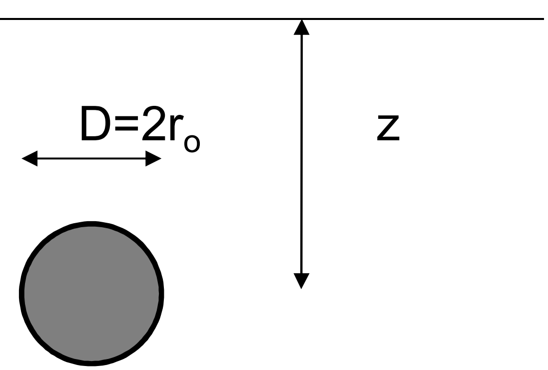
  - k=thermal conductivity (W/mK, note: W=J/s)
  - r_j=inner radius of layer j

The heat transferr coefficient

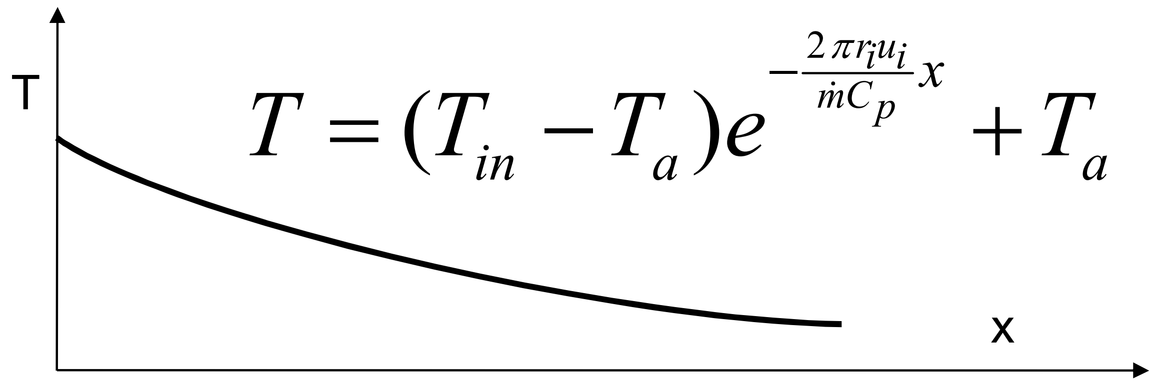
- **For insulated flowlines the heat transferr is governed by the insulation and the soil cover**

$$u_i = \frac{1}{r_i\left(\frac{1}{k_{soil}}\cosh^{-1}\frac{z}{r_o} + \sum\frac{\ln(\frac{r_{j+1}}{r_j})}{k_j}\right)}$$

$$h_{soil} = \frac{k_{soil}}{r_o \cosh^{-1}(\frac{z}{r_o})}$$



Steady state temperature profile



$$T = (T_{in} - T_a)e^{-\frac{2\pi r_i u_i}{\dot{m} C_p} x} + T_a$$

- T_{in} = Inlet temperature
- T_a = Ambient temperature (°C)
- $\dot{m}$ = mass flux (kg/s)
- C_p = Specific heat capacity (J/(kgK)
- x = distance from inlet (m)

Time from shut-down to critical hydrate temperature is reached

- **"The lumped capacity model":**
  - Only valid if the temperature gradient is governed by a thin insulation layer
  - For thick layer insulation (e.g. buried pipes) more advanced mehtods such as finite differences need to be used

$$t = \frac{\sum m_j C_{pj}}{u_i 2\pi r_i} \ln\left(\frac{T_s - T_a}{T_c - T_a}\right)$$