

Heat Transfer with Phase Change

So far we have discussed heat transfer due to a temperature gradient/difference

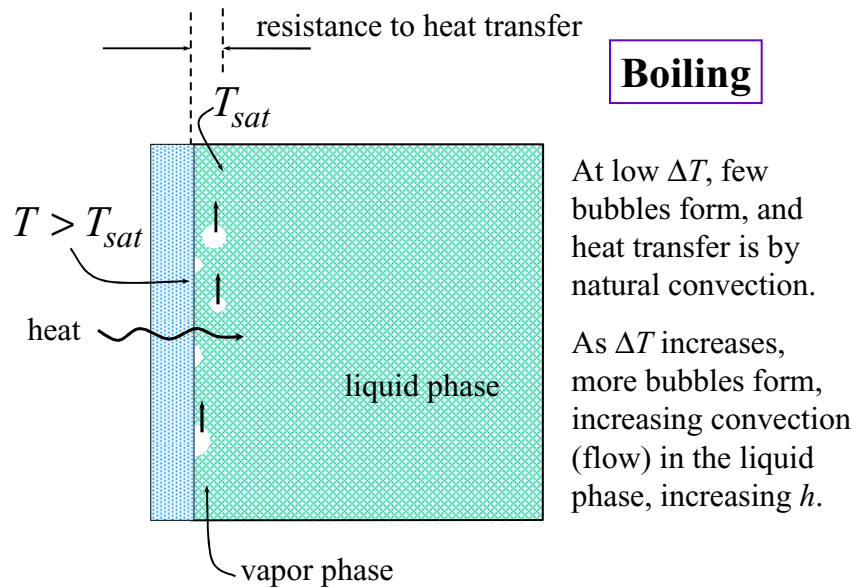
$$\frac{q_x}{A} = -k \frac{dT}{dx} \quad \text{conduction}$$

$$\frac{q_x}{A} = h(T_b - T_w) \quad \text{convection}$$

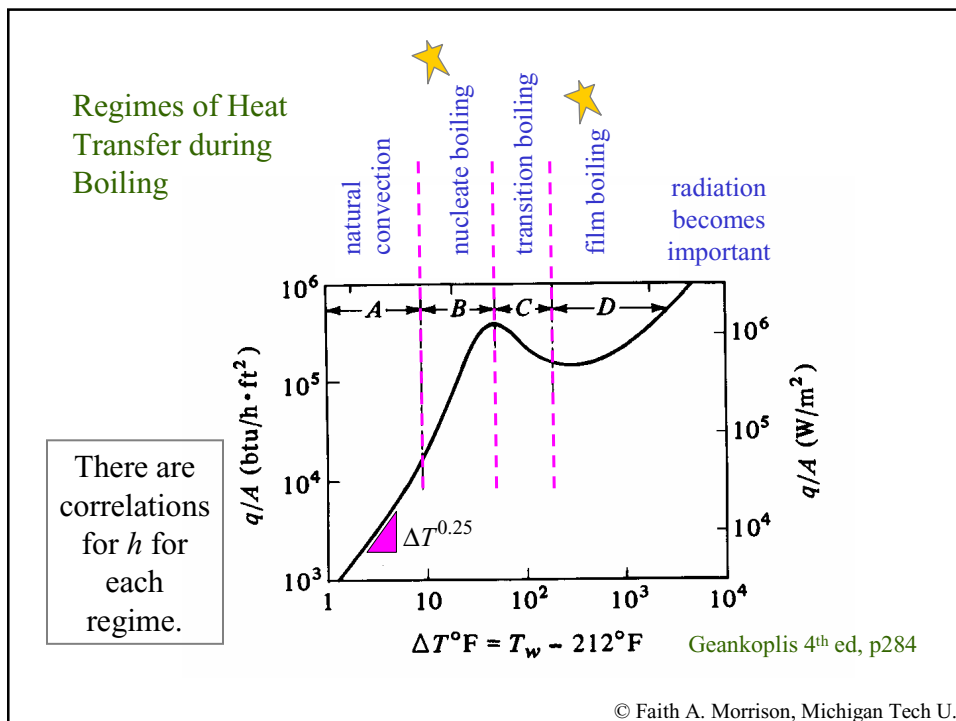
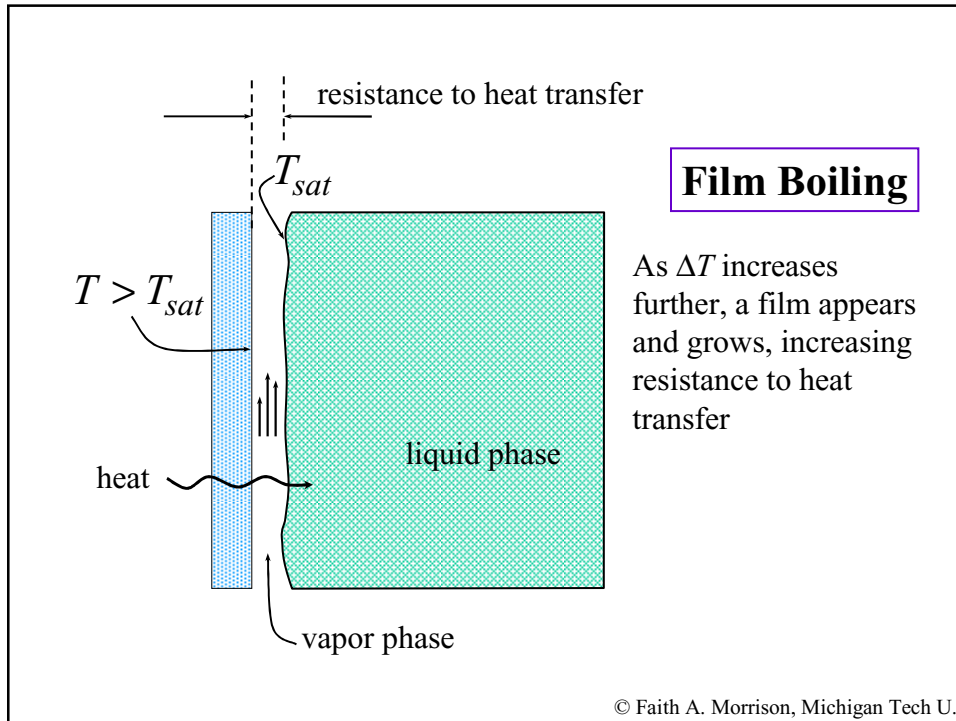
When a phase change takes place, the temperature on one side is **CONSTANT**, but the presence of boiling/condensing fluids affects heat transfer.

- Important in evaporation, distillation
- **LARGE h**

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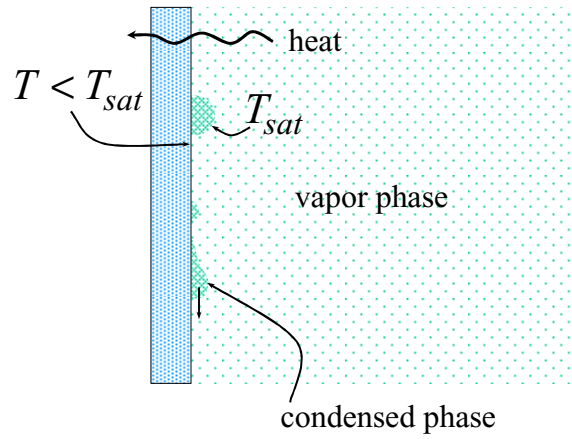


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Dropwise Condensation

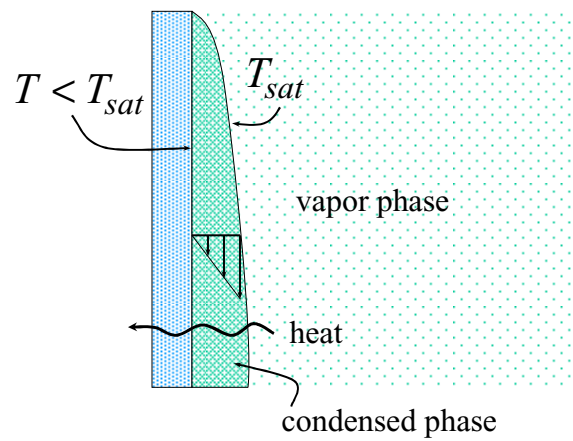
- high h
- hard to maintain
- not used in practice



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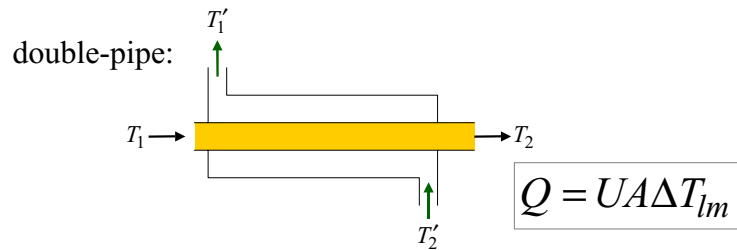
Film Condensation

- film reduces h
- very stable
- often used



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Heat Exchangers



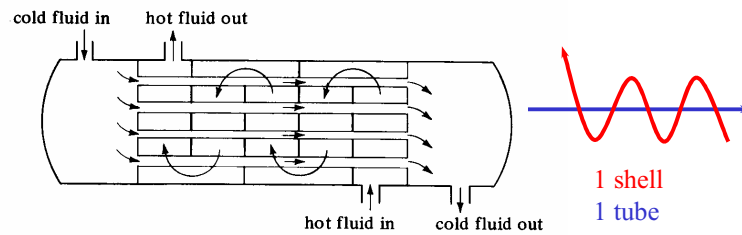
To increase Q appreciably, we must increase A , i.e. R_i

But:

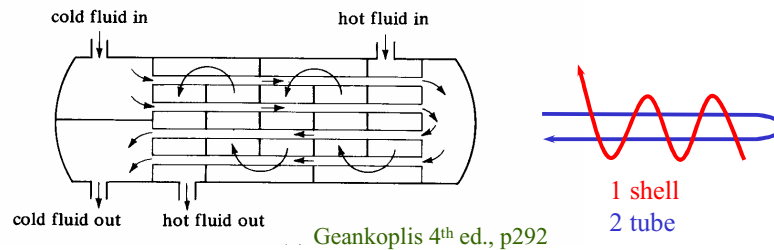
- only small increases possible
- increasing R_i decreases h

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1-1 Shell and Tube Heat Exchanger



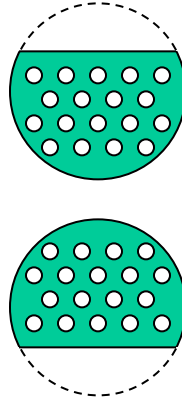
1-2 Shell and Tube Heat Exchanger



Geankoplis 4th ed., p292

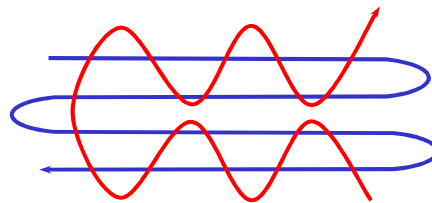
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Cross Baffles in Shell-and-Tube Heat Exchangers



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And other more complex arrangements:



2 shell
4 tube

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For double-pipe heat exchanger:

$$Q = UA\Delta T_{lm}$$

For shell-and-tube heat exchangers:

$$Q = UA[\Delta T_{lm}(F_T)]$$

$\underbrace{\hspace{10em}}_{\equiv \Delta T_m}$

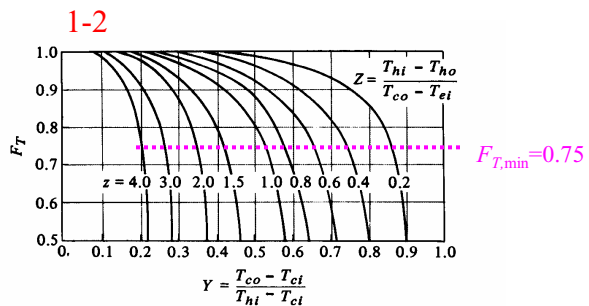
$\equiv \Delta T_m$ correct mean temperature difference for shell-and-tube heat exchangers

calculated correction factor
 (obtain from charts)

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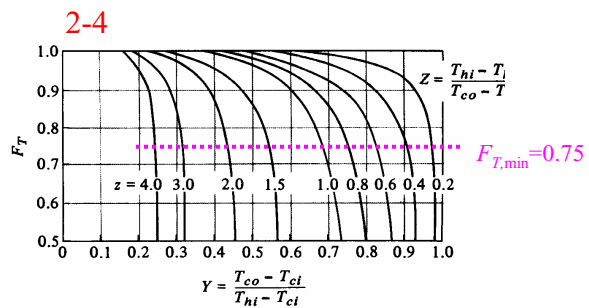
F_T Shell-and-Tube Heat Exchangers

(1-1 exchanger, $F_T = 1$)



T_{hi} = hot, in
 T_{ho} = hot, out
 T_{ci} = cold, in
 T_{co} = cold, out

Geankoplis 4th ed., p295

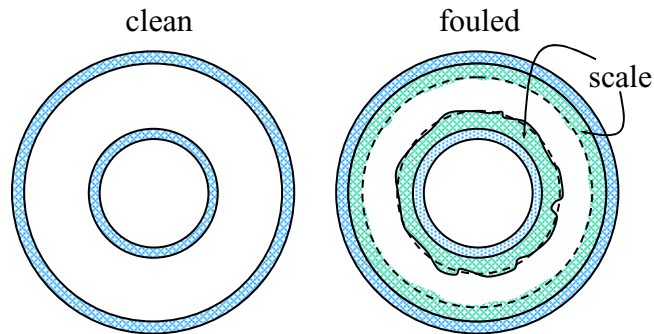


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Heat Exchanger Fouling

- material deposits on hot surfaces
- rust, impurities
- strong effect when boiling occurs

scale adds an additional resistance to heat transfer



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Heat transfer resistances

$$U_{i\ or\ o} = \frac{1}{\frac{1}{h_i R_i} + \frac{1}{k} \ln\left(\frac{R_o}{R_i}\right) + \frac{1}{h_o R_o}}$$

resistance due to interface

resistance due to limited thermal conductivity

add effect of fouling

$$U_{i\ or\ o} = \frac{1}{\frac{1}{h_i R_i} + \frac{1}{h_{di} R_i} + \frac{1}{k} \ln\left(\frac{R_o}{R_i}\right) + \frac{1}{h_{do} R_o} + \frac{1}{h_o R_o}}$$

see Perry's Handbook, or Geankoplis 4th ed.
Table 4.9-1, page 300 for values of h_d

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