DESIGN CALCULATION

LMTD

A Methodology for Heat Exchanger Design Calculations

- The Log Mean Temperature Difference (LMTD) Method -

- A form of Newton's Law of Cooling may be applied to heat exchangers by using a log-mean value of the temperature difference between the two fluids:

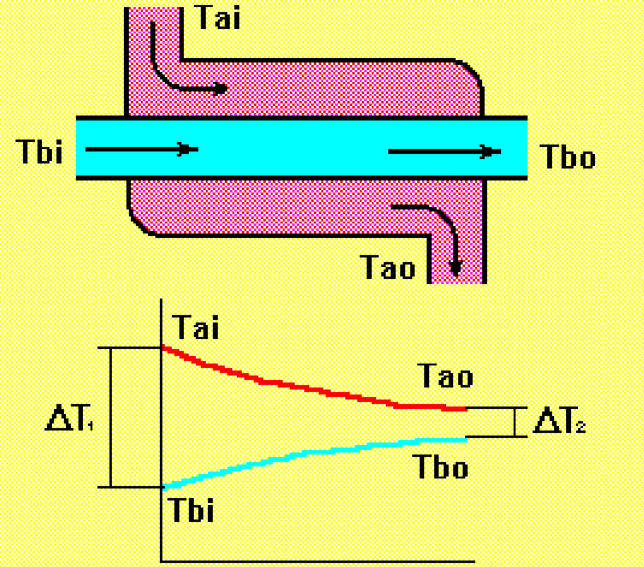
$$q = U\,A\,\Delta T_{1m}$$

$$\Delta T_{1m} = \frac{\Delta T_1 - \Delta T_2}{1n\left(\Delta T_1 / \Delta T_2\right)}$$

Evaluation of ΔT_1 and ΔT_2 depends on the heat exchanger type.

Koefisien Transfer Panas Menyeluruh (U)

$$U = \frac{1}{\frac{1}{h1} + \frac{\Delta x}{k} + \frac{1}{h2}}$$



Temperature distribution along tube axis.

TEMPERATURE terms

- **Approach temp. :**
  temperature difference in one terminal (inlet / outlet)

Batasan umum :

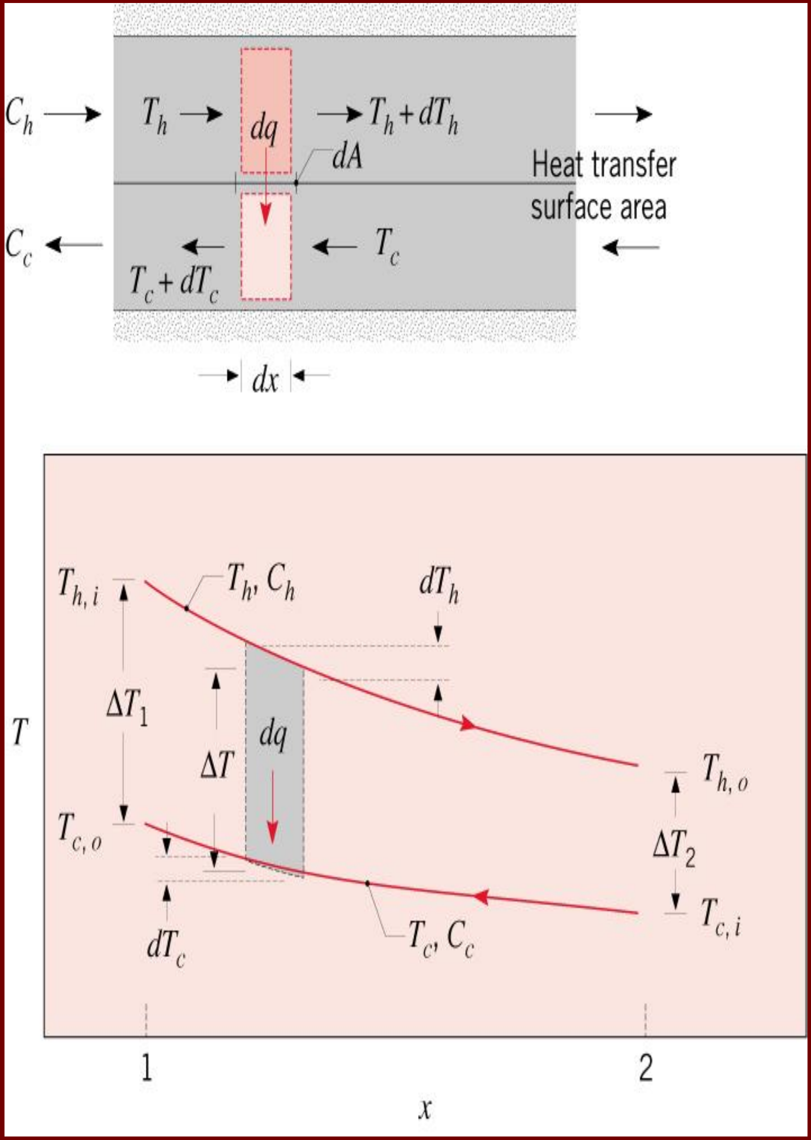
ΔT app. : 10-20 F utk suhu ambient hingga 300 F
1-2 F atau < 10 F utk cryogenic & < ambient
~ 100 F utk suhu tinggi

- **Range temp. :**
  the actual temp. rise / fall

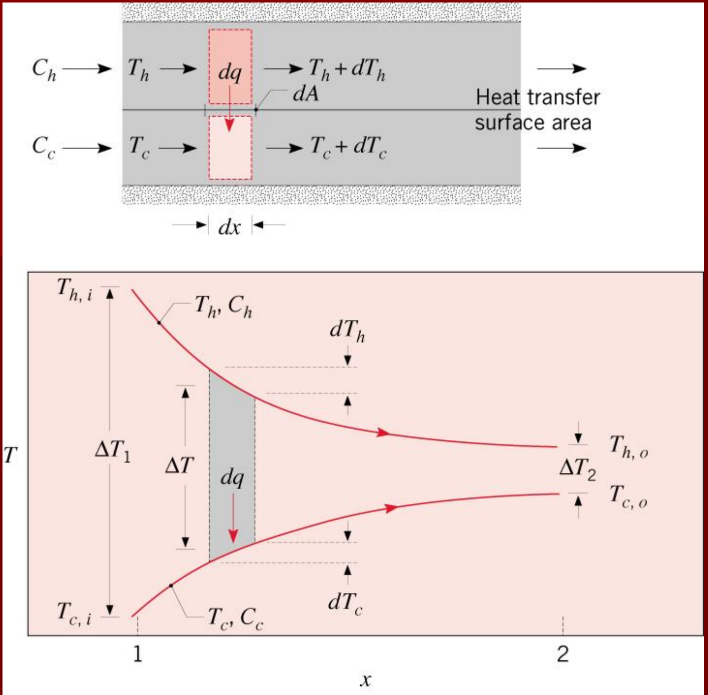
- Counter-Flow Heat Exchanger:

$$\Delta T_1 \equiv T_{h,1} - T_{c,1}$$
$$= T_{h,i} - T_{c,o}$$

$$\Delta T_2 \equiv T_{h,2} - T_{c,2}$$
$$= T_{h,o} - T_{c,i}$$



- Parallel-Flow Heat Exchanger:



$$\Delta T_1 \equiv T_{h,1} - T_{c,1} = T_{h,i} - T_{c,i}$$

$$\Delta T_2 \equiv T_{h,2} - T_{c,2} = T_{h,o} - T_{c,o}$$

- Note that $T_{c,o}$ can not exceed $T_{h,o}$ for a PF HX, but can do so for a CF HX.
- For equivalent values of UA and inlet temperatures,

$$\Delta T_{1m,CF} > \Delta T_{1m,PF}$$

Soal 1

- Fluida panas memasuki pipa konsentris pada suhu 300 F dan didinginkan hingga 200 F menggunakan fluida dingin yg masuk pada suhu 100 F dan keluar bersuhu 150 F.

    a. Berapa nilai ΔT lmtd ?

    b. Susunan mana yg lebih baik, paralel atau lawan arah ?

Soal 2

- Diinginkan untuk memanaskan 9820 lb / hr benzene dari suhu 80 F menjadi 120 F, menggunakan toluen panas bersuhu 160 F yang akan mendingin menjadi 100 F.

A. Berapa laju alir toluen yang dibutuhkan untuk keperluan ini ?
B. Bila nilai U = 115 Btu/hr.ft2.F, berapa luas transfer panas yg diperlukan?
C. Jenis HE apa yang sesuai ?

Soal 3

- Diinginkan untuk mendinginkan 33114 lb / hr butanol dari suhu 210 F menjadi 105 F, menggunakan air bersuhu 95 F yang akan memanas menjadi 105 F.

A. Berapa laju alir air yang dibutuhkan untuk keperluan ini ?
B. Bila nilai U = 200 Btu/hr.ft2.F, berapa luas transfer panas yg diperlukan?
C. Jenis HE apa yang sesuai ?

- Shell-and-Tube and Cross-Flow Heat Exchangers:

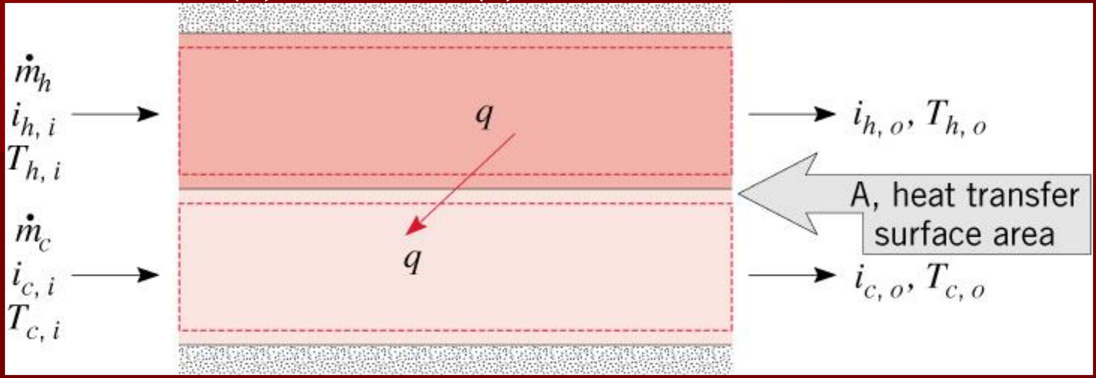
$$\Delta T_{1m} = F \; \Delta T_{1m,CF}$$

↓

Grafik F di Kern utk berbagai susunan HE (fig.18-23 Appendix)

Overall Energy Balance

- Application to the *hot (h)* and *cold (c)* fluids:



- Assume negligible heat transfer between the exchanger and its surroundings and negligible potential and kinetic energy changes for each fluid.

$$q = \dot{m}_h \left(i_{h,i} - i_{h,o} \right)$$

$$q = \dot{m}_c \left(i_{c,o} - i_{c,i} \right)$$

$$i \rightarrow \text{ fluid enthalpy}$$

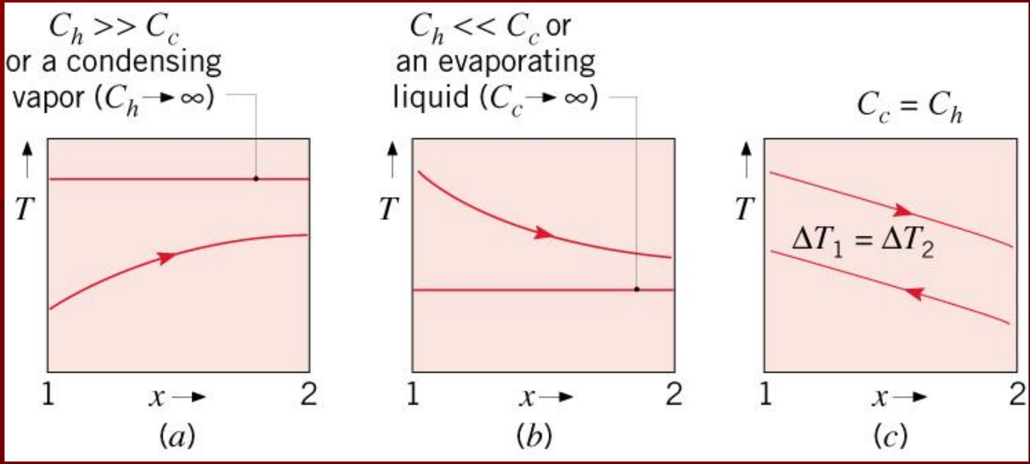
- Assuming no *l/v* phase change and constant specific heats,

$$q = \dot{m}_h c_{p,h} \left(T_{h,i} - T_{h,o} \right) = C_h \left(T_{h,i} - T_{h,o} \right)$$

$$q = \dot{m}_c c_{p,c} \left(T_{c,o} - T_{c,i} \right) = C_c \left(T_{c,o} - T_{c,i} \right)$$

$C_{h,} C_c \rightarrow$ Heat capacity rates

Special Operating Conditions



- Case (a): $C_h >> C_c$ or h is a condensing vapor $(C_h \to \infty)$.
  - Negligible or no change in $T_h\left(T_{h,o} = T_{h,i}\right)$.
- Case (b): $C_c >> C_h$ or c is an evaporating liquid $(C_c \to \infty)$.
  - Negligible or no change in $T_c\left(T_{c,o} = T_{c,i}\right)$.
- Case (c): $C_h = C_c$.
  - $$\Delta T_1 = \Delta T_2 = \Delta T_{1m}$$

Tahapan perancangan HE

- Menentukan beban panas
  - kec. Transfer panas (q)
  - kec. Alir massa (m)
  - suhu
- Menentukan sifat fisis fluida (panas / dingin) : μ, ρ, Cp, k, dll
- Mengestimasi nilai U_D
- Menghitung nilai ΔT, A (dari pers. $Q = UA\ \Delta T$)

Cont'd

- Menentukan jenis HE (DPHE < 200 ft^2)
- Menentukan panjang pipa (L), jumlah tube (Nt), ID, OD, BWG (tebal pipa, Birmingham Wire Gauge)
- Menentukan lay out pipa (jenis pitch & P_T)
- Menghitung h_i, h_o, h_{io} (h_{io} = hi * (ID/OD)
- Menghitung Uc dan Rd

  Uc = (hio.ho)/(hio+ho)

  Rd = (Uc-Ud)/(Uc.Ud)

* Menghitung pressure drop (Δp) pipa & shell

Pertimbangan desain

- Penempatan fluida

  - tubes :

  utk fluida yang korosif, *fouling, hazardous, scaling, bertekanan tinggi, bersuhu tinggi, bernilai tinggi (mahal)*

  OD <<, Δp >> → fouling terjadi lebih cepat

  OD >>, v <<, Re << → h <<

  triangular pitch : turbulensi >> → h >>, Δp >>

  square pitch : turbulensi << → h <<, Δp <<

- D tubes umumnya : 5/8 " – 1/12 "
- Panjang tubes : 6, 8, 12, 16, 20 ft
- Jumlah pass : 1 - 16

- shell :

  utk fluida yang lebih viskos, lebih bersih, flow rate rendah, serta *evaporating & condensing fluids*

  baffle → meningkatkan turbulensi (ho >>)

  tinggi baffle umumnya 75% ID shell

  B : (1/5 – 1).ID shell