CM3215

MichiganTech

Fundamentals of Chemical Engineering Laboratory

Overall Heat Transfer Coefficient for Double-Pipe Heat Exchanger

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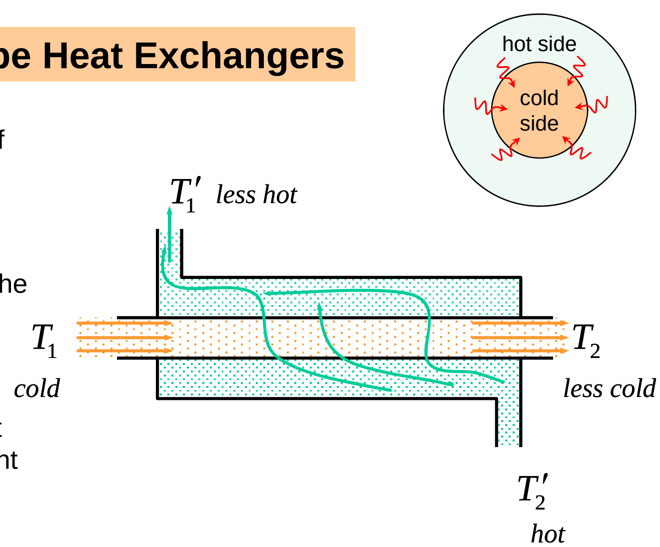
Double-Pipe Heat Exchangers

- Simplest type of heat exchanger
- Total heat transferred proportional to the log-mean temperature difference
- Counter-current shown; co-current also possible



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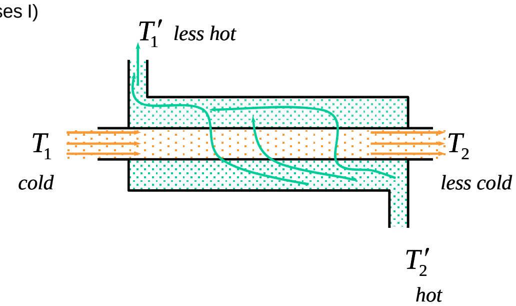
Double-Pipe Heat Exchangers

(Covered in CM3110 Transport Processes I)

Steady state, macroscopic, open-system energy balance on:

- •Inside
- •Outside
- •Overall



Reference: Felder and Rousseau

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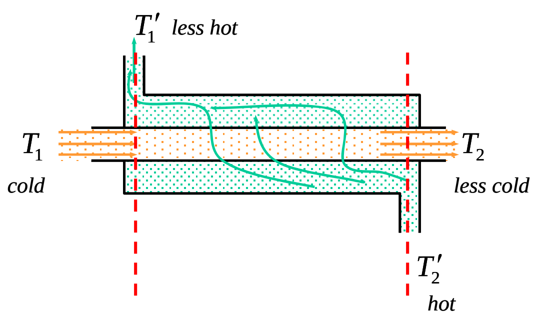
Double-Pipe Heat Exchangers



$\Delta T_{left} = (T_1' - T_1)$

$\Delta T_{right} = (T_2' - T_2)$

- ***ΔT = driving force for heat transfer***
- ΔT **varies down the length** of the heat exchanger (HE)
- Amount of heat transferred **varies down the length** of the HE

("left" and "right" are only for this example and may change for your heat exchanger.)

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Double-Pipe Heat Exchangers

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- ΔT **varies down the length** of the heat exchanger (HE)
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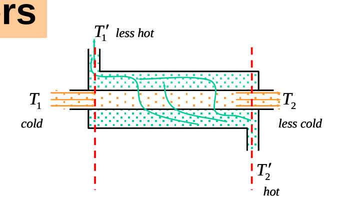

$\Delta T_{left} = (T_1' - T_1)$

$\Delta T_{right} = (T_2' - T_2)$

The **overall heat transferred *Q*** is governed by the average driving force, $\Delta T_{average}$

The **correct average** driving force (as we show in CM3110) is the **log mean ΔT**

Comes from considering the energy balances)

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Log Mean ΔT Driving Force

The amount of heat transferred is governed by **the log mean driving force**

Driving temperature difference at one end of heat exchanger

Driving temperature difference at the other end of heat exchanger

$$\Delta T_{lm} \equiv \frac{(T_1' - T_1) - (T_2' - T_2)}{\ln\left(\frac{T_1' - T_1}{T_2' - T_2}\right)}$$

Note: the log-mean average temperature driving force will be a number <u>between</u> these two ΔT's

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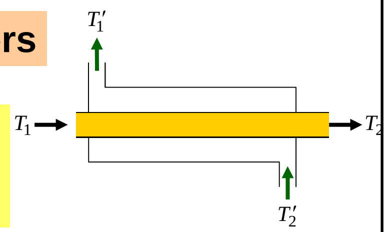
Double-Pipe Heat Exchangers

- **Total Heat Transferred given by Q**
- **The HE is characterized by its overall heat transfer coefficient, U**



$$Q = UA\Delta T_{lm}$$
$$= U(2\pi R_{outer}L)\Delta T_{lm}$$
$$U \equiv \frac{Q}{A\Delta T_{lm}}$$

(note: we choose R_{outer} to define U; we could have used R_{inner}; it's arbitrary)

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Where do we get A? (the area across which heat is transferred)

From the Equipment Schedule (see website):

$$U \equiv \frac{Q}{A\Delta T_{lm}}$$

8/17/2001
DWC

Department of Chemical Engineering
Michigan Tech University

Equipment Schedule for Fundamentals of CM Laboratory Apparatus

Tag	Location of Device	Comments	Product	Flowrate	Specific Gravity	Temp., deg. F
E-01	Above branched piping circuit	Double-pipe Heat Exchanger, Shell-2"Sched. 40 C.S. pipe, Tube-3/8" o.d. type L copper tubing, 48" long.	City Water/ Steam	5.12 GPM	1	55
P-01	Below bench	3 gpm@71 ft. head, 1 1/4"x1", 120/240 VAC, 1ph., 1/2 hp open drip-proof motor	City Water	5 GPM	1	55
T-01	Below W007 outlet	Tank, 10 gallon, heavy wall PE, 18 3/4"h x 13" o.d.	City Water	5 GPM	1	55
T-02	Below W008 outlet	Tank, 10 gallon, heavy wall PE, 18 3/4"h x 13" o.d.	City Water	5 GPM	1	55

Key to Miscellaneous Identifiers	
PT-##	Pressure Tap
T#	Steam Trap

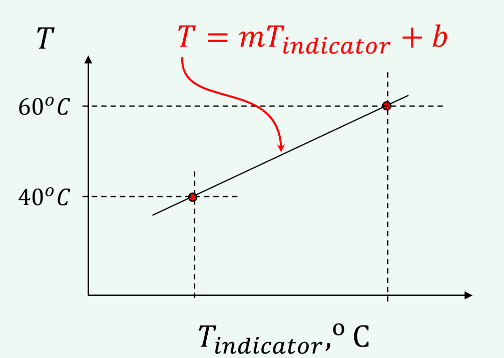
(note: A is not the pipe cross section!)

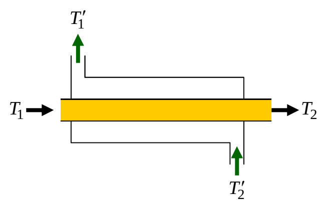
Where do we get ΔT_{lm}? (average driving force for heat transfer)

Measure the temperatures with calibrated thermocouples.

$$U \equiv \frac{Q}{A\Delta T_{lm}}$$

Two-Point Temperature Calibration

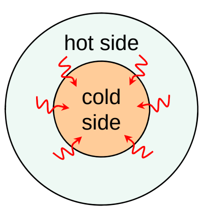


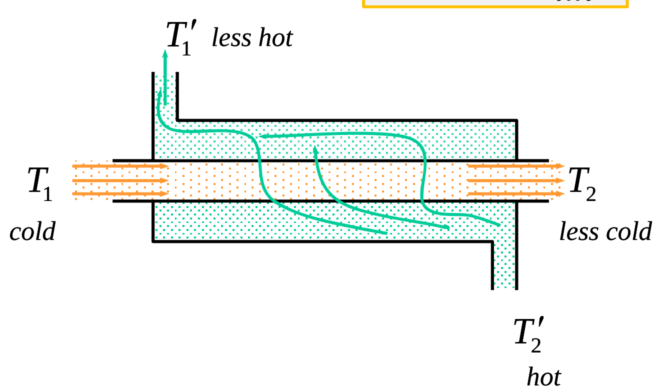


$$\Delta T_{lm} \equiv \frac{(T_1' - T_1) - (T_2' - T_2)}{\ln\left(\frac{T_1' - T_1}{T_2' - T_2}\right)}$$

Where do we get Q? (the amount of heat transferred)

$$U \equiv \frac{Q}{A\Delta T_{lm}}$$





Let's calculate.

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We will record data (and first calculations) on the white board in class – be prepared to do so

- Temperatures
- ΔT_{lm}
- Heat flow (steam side) (pail and scale)
- Heat flow (water side) (rotameter)
- $U\left(\frac{W}{m^2K}\right)$, based on water side Q
- $U\left(\frac{W}{m^2K}\right)$, based on steam side Q

Answer the Google form to submit your data – please be prompt!

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How do we measure Q?

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- Temperatures
- ΔT_{lm}
- Heat flow (stea
- Heat flow (wat
- $U\left(\frac{W}{m^2K}\right)$, base
- $U\left(\frac{W}{m^2K}\right)$, based

- Two ways:
  - ✓ Water side
  - ✓ Steam side
- Perform *Macroscopic Energy Balances* to obtain Q
- Check if HE is adiabatic

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Macro-E-Balance comes from CM2110 and CM2120; see our handout page for Dr. Morrison's E- Balance Notes: www.chem.mtu.edu/~fmorriso/cm310/Energy_Balance_Notes_2008.pdf

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Report 6: Overall Heat Transfer Coefficient for Double-Pipe Heat Exchanger

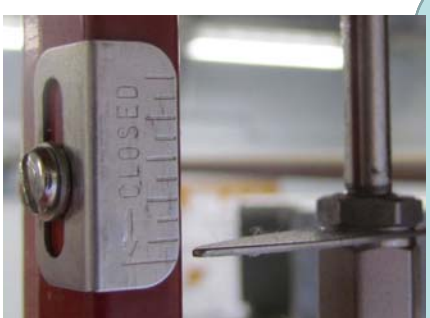
- Calibrate thermocouples
- Pump water through inner pipe of double-pipe heat exchanger (rate determined by rotameter)
- Flow steam through outer pipe of double-pipe heat exchanger (measure rate by pail and scale)
- Allow to come to steady state (monitor; *graphically* demonstrate steady state in your report)
- Measure appropriate temperatures, flow rates, and replicates
- Share raw data with classmates
- Calculate and report **overall heat transfer coefficient**; use two different methods of calculating Q
- Report the process of achieving steady state
- Address all objectives in assignment memo

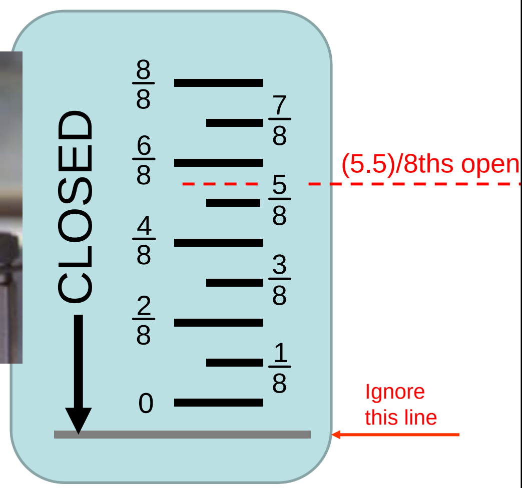
Pneumatic Valve Position

Note: The position of the valve stem is read from a set of notches based on 1/8th distance per notch:

(compare to a 12 inch ruler)

x= fraction open





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Prelab Assignments:

- Calculate the heat transfer area of the double pipe heat exchanger in the lab. Base your calculation on the outside area of the inside pipe. Retain extra sig figs since this is an intermediate calculation.
- Calculate the rotameter setting for the desired water-side flow rate; write in your lab notebook.
- Fit the latent heat of vaporization of steam over a reasonable temperature range (near atmospheric pressure) to an empirical function. You can use this in the lab to get $\Delta H_{vap}(T_{steam-side})$. Affix the plot with the correlation in your lab notebook.
- Answer question: If $T_2 - T_1 = 76^oC$, what is ΔT in units of K?
- Prepare a safety section with care—this lab is different than all the rest

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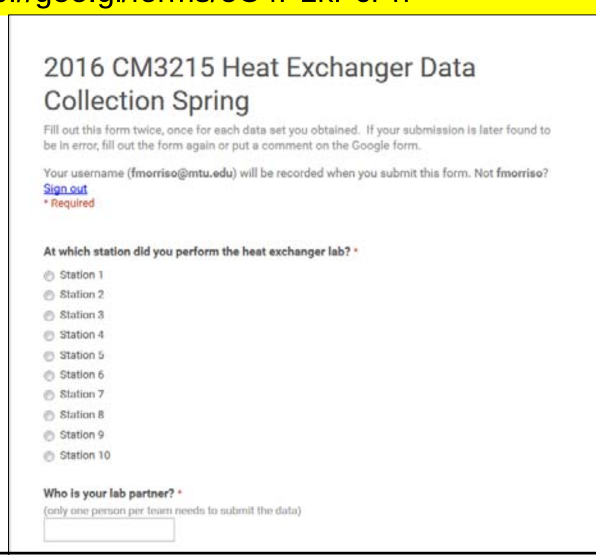
Submit your raw data to the Google form by Thursday 5pm at the latest.

http://goo.gl/forms/eC4P1kPcPh



2016 CM3215 Heat Exchanger Data Collection Spring

Fill out this form twice, once for each data set you obtained. If your submission is later found to be in error, fill out the form again or put a comment on the Google form.

Your username (**fmorriso@mtu.edu**) will be recorded when you submit this form. Not **fmorriso**? Sign out

* Required

At which station did you perform the heat exchanger lab? *

- Station 1
- Station 2
- Station 3
- Station 4
- Station 5
- Station 6
- Station 7
- Station 8
- Station 9
- Station 10

Who is your lab partner? *

(only one person per team needs to submit the data)