Written Communication

Mark J. McCready
4/7/16

Outline

- Some London (reprise) items

- Writing reports

A few items for clarification

- Recommended website:http://londontopia.net

  - 101 "free things" mentioned several of the mjm "to dos"

    - e.g., the Thames tunnel, St. Pancras and Trafalgar Square

      - (but not to count the "Prets")

    - http://londontopia.net/101-free-things-to-do-in-london/

Suggestions

- If you are not coming with the group..

    - Piccadilly line from Heathrow

    - but not during "rush hour"

- Need cash/(coins) for some fraction of public restrooms,

    - 20, 30 40 pence, 1 Euro at the Paris Train station.

    - (much lower density of public restrooms in UK and Europe in general than US.)

- Need cash for "busking musicians"

    - They have auditions for key locations:

        - https://www.coventgarden.london/culture/street-performers

- and "pan handlers"…

    - or not… but if someone is asking you where you are going, he does know the way!

- Small sales at small shops, street vendors, etc.

Prequel

- Because of instant, electronic communication, writing is more important that it had been previously

  - particularly the ability to craft a good message in just a few words, in a short amount of time.

- Also, everyone is "busier" than in previous generations (at least we think we are -- I suppose we are keeping up with our instant communication!) so they will read only the minimal amount of everything

  - This is an opportunity for those of you who are good at it

- Ideally, you could think of report writing as a chance to be getting better at an essential skill!

Outline

- First you need content (good data) and sound understanding

- General thoughts and principles of technical writing

  - Be clear and efficient

  - Correct grammar is important

- **Introduction**

- **Theory**

- **Experiment**

- **Graphs**

- **Discussion**

- **Abstract**

General thoughts

- You are not writing to fill up space

- You should **respect** the time and effort of the reader

- The reader should get exactly the conclusions that you are trying to convey --

    - if the "fix" to a process is a 10C <u>decrease</u> in temperature, you don't want the reader thinking it is a 10C increase!

    - Ethanol from corn is fundamentally a bad idea and so the reader should not get the end and not be sure of this.

- Generally 3rd person, save 1 or 2 "we's" for emphasis (not in abstract)

- Use consistent verb tense. You did the experiment in the past. But, you can state the results in the present (or past), just don't switch back and forth.

    - If I am particularly confident about the results, I would be inclined to state them in the present!!

Introduction

> **4. Introduction**
>
> The purpose of the Introduction is to place the work in the perspective of prior work including key literature references, demonstrate its importance, and state the specific objectives. The Introduction should not exceed two pages.

- This is your chance to "capture the imagination" of the reader by <u>describing the technology importance of the topic of the laboratory experiment</u>.

- You get just one chance… the first couple of sentences… and if it works don't over do it and if it doesn't don't belabor it!

- "Almost all of the electricity that powers modern civilization is generated through the use of a Rankine Cycle in which steam generated by burning of fossil fuels or from a nuclear reaction passes through a turbine that turns a generator…"

- At this point you could write about the history or something about the sources of energy, even something about pollution controls.

Introduction (continued)

- You could mention how Rankine differs from some other power cycles and why it is preferred or how it works with combined heat and power.

  - More generally, give considerations for use of different devices or process configurations (at the end of the day engineers always pick an optimal configuration.)

- What steam pressures are generated and why? How does a turbine work? (Why isentropic)

  - For all of these, you need to cite references.

  - We know you will not be writing something no one has thought of however:

    - all of the writing needs to be original to you!

Heat exchanger/pipe flow

- For the heat exchanger experiment, perhaps I would write something more specific:

- …" To efficiently accomplish heat exchange, in almost all technologies, tradeoffs exist between the power to pump fluids through long, small passages and the need to minimize the volume or floor area of the heat exchanger"

- For pipe flow, the same basic engineering (or physiological) optimization principle exists that… "while diameter must be increased to accommodate larger flow rates, there is an important tradeoff between the diameter of a pipe and the power to pump through an "operating cost— capital cost" optimization principle."

- The other "stock statement" that you could make in an introduction is the importance of verifying how well the device is working (to learn, in the case of these experiments, and to make sure you are not dumping tons of HCs into the air per minute, in the case of a refining process…)

  - with inside gained "after the fact", you could "hint" at what you would be looking for to verify good operation.

"Theory"

- Could start with a statement of the physical law(s) that are governing the process that you are studying. (e.g., momentum conservation, energy conservation, phase equilibrium, rate of approach to equilibrium…)

- Then, look at the calculations necessary to turn your raw data into the points on the graphs or tables and explain how this fundamental principles supports the equations that you used.

  - Usually there are 2-3 main calculations and hence equations worthy of emphasis in the theory. (sample calculations are in the appendix)

- For, say the heat exchanger, the fundamental equation is (duh), conservation of energy!

  - You will want to state this and then show the equations that are used to implement this principle in your experiment, including how you get to statements of efficiency" or "heat losses"

- The other principle is "Newton's Law of Cooling", which defines a heat transfer coefficient in terms of a flux and a temperature gradient. This is the essential equation in design of a heat exchanger (how much transfer area is required) and central to the optimization principle mentioned above.

Experiment

- **See instructions**

- Apparatus

  - photo and digram is probably appropriate.

    - description of how it works and ranges of variables are appropriate

- Procedure

  - Brief synopsis of the aspects of running the device that are not obvious or which are <u>essential for getting good results</u>

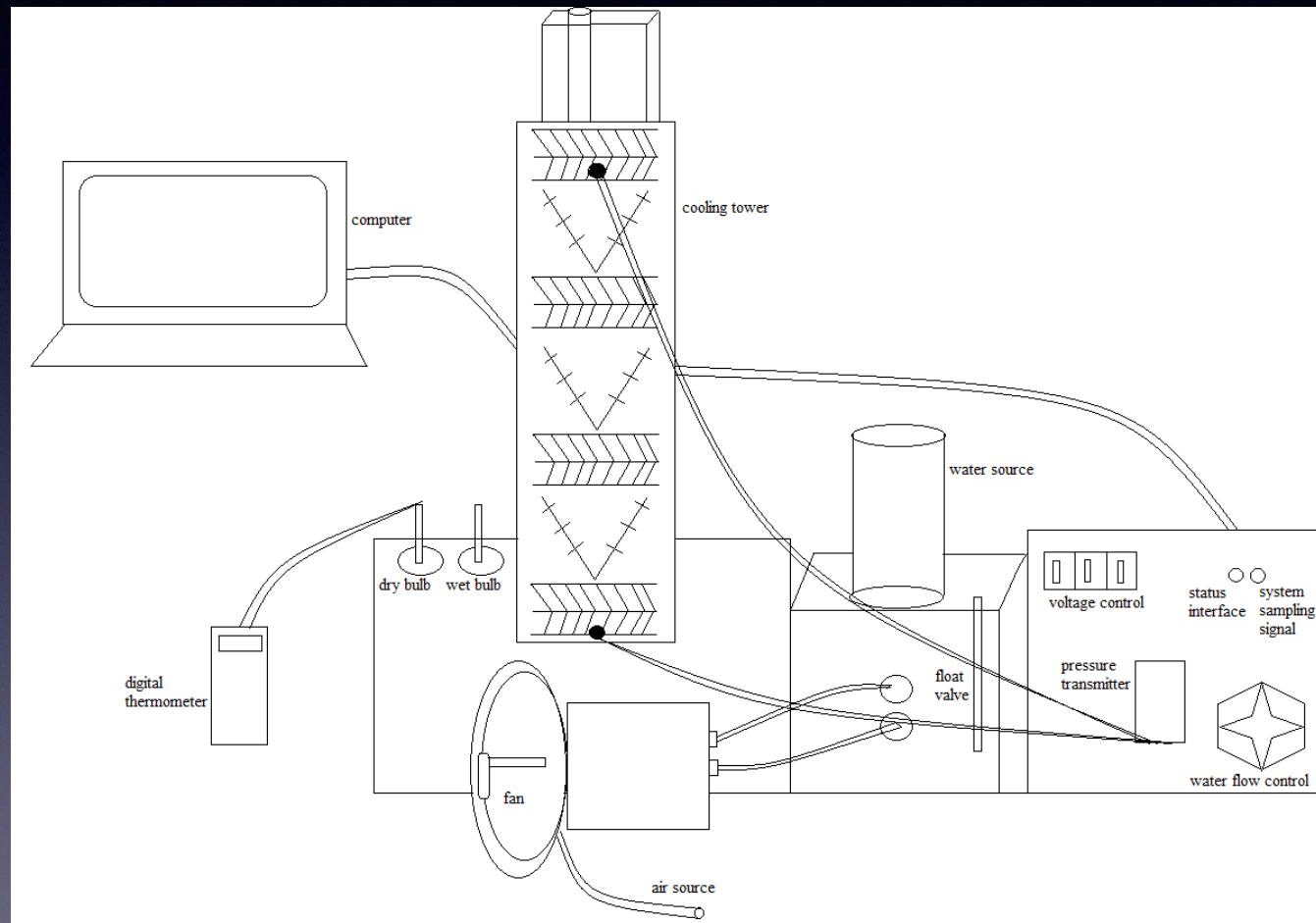# Water cooling tower

schematic of experiment

Figure 3. Computer-Linked Bench Top Cooling Tower Schematic

Experimental technique matters!
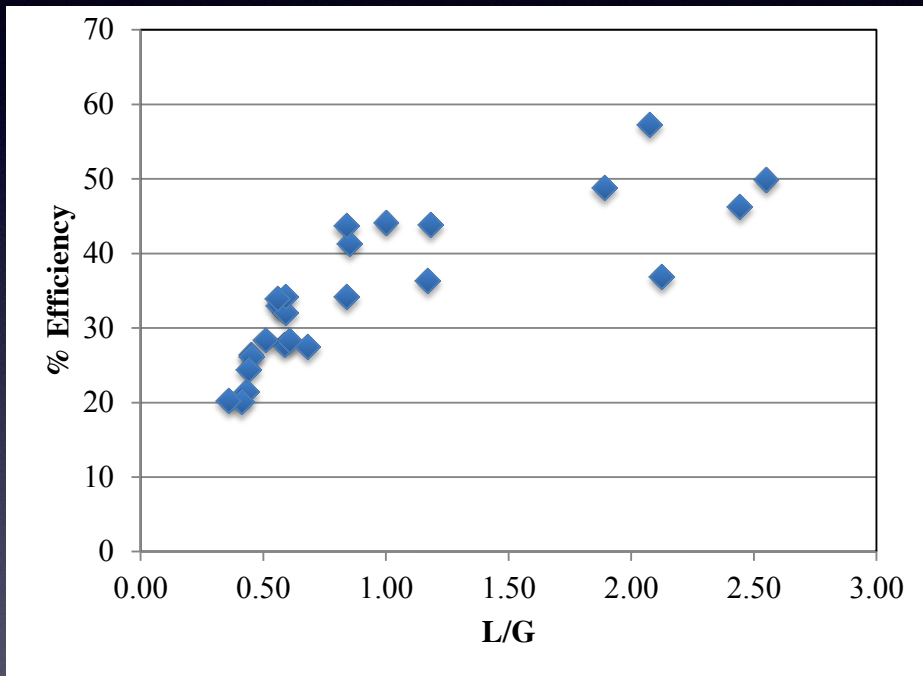
plots should have error bars

Figure 6. Percent Efficiency of the cooling tower as a function of L/G input.
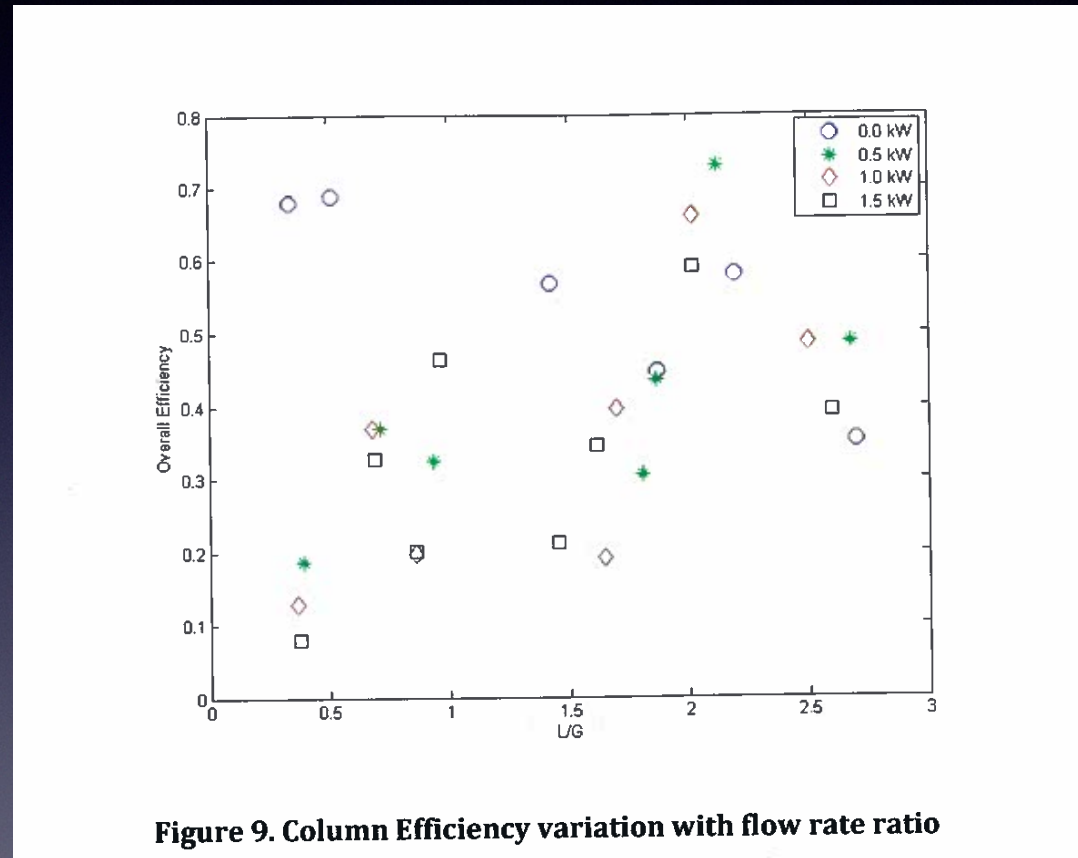

Figure 9. Column Efficiency variation with flow rate ratio

It matters who is driving!

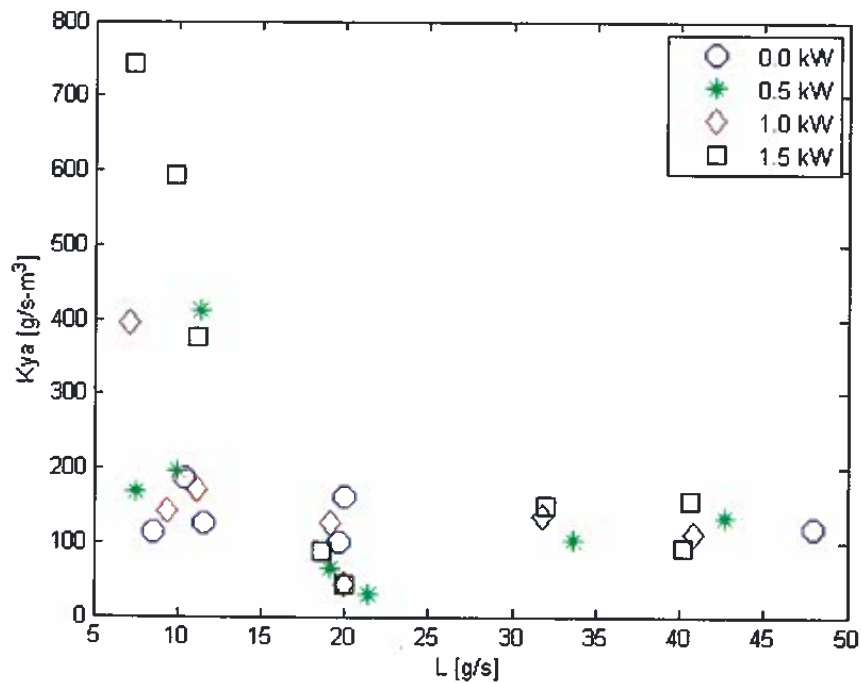## plots should have error bars

Figure 6. Variation of $K_y a$ with Liquid flow rate
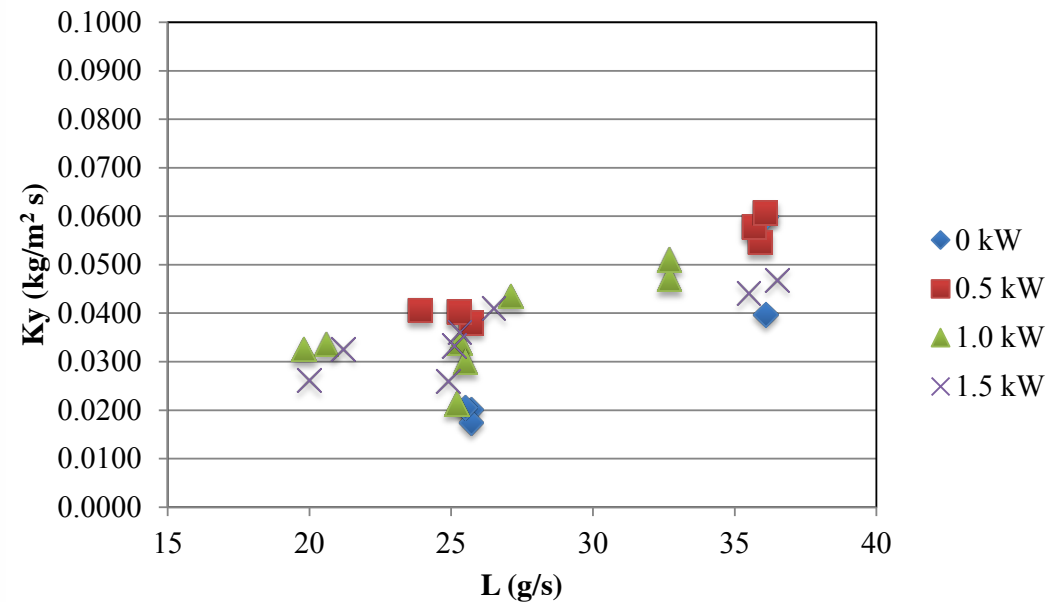
Figure 5. Ky as a function of water flow rate input for various powers.

Results

- Start with the graphs that you think are most important (or tables if necessary)

- Fill in some prose to explain to the reader significant of what he or she is seeing.

Graphs

- Readability is critical

- Datum are single points

  - Never just draw a line through the data!

  - Data always come with a calculation of uncertainty (a.k.a error!)

- Theory and correlations are "lines"

- Where is "0"?

Figure 1. Reynolds number - Friction factor data for all pipes
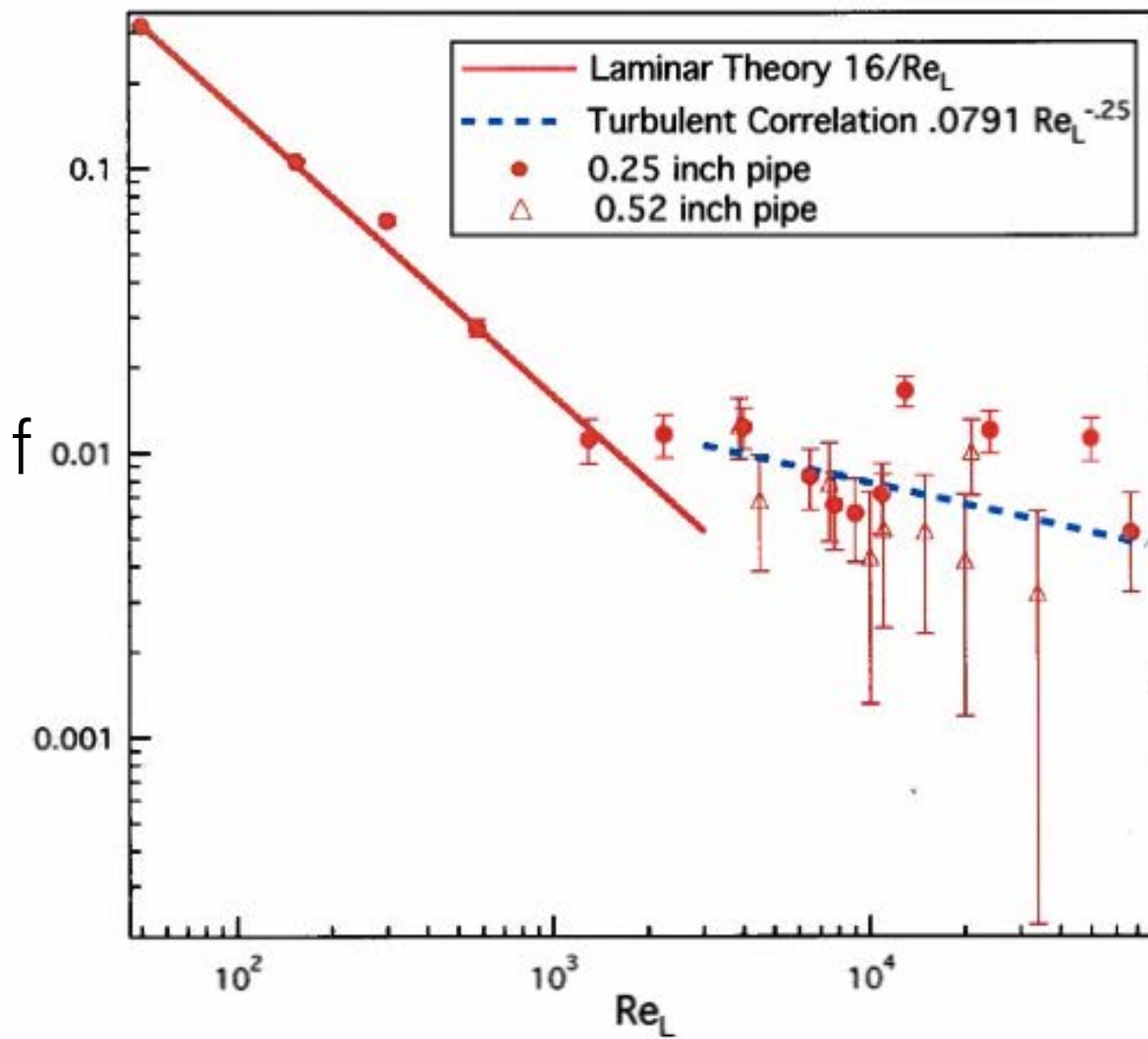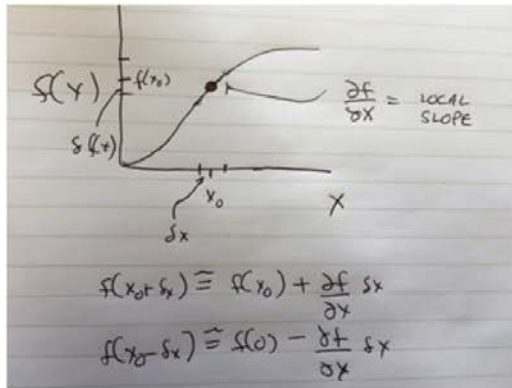
Uncertainty in measurements

- Uncertainty for individual data points usually is determined by "propagation of error"

Total differentials as a basis for error

For a simple function, say f(x), the range of error/uncertainty of f(x) caused by an error in the measurement of x is given by the local slope, $\partial f/\partial x \pm \delta x$

$$f(x_0 + \delta_x) \cong f(x_0) + \frac{\partial f}{\partial x} \delta_x$$

$$f(x_0 - \delta_x) \cong f(0) - \frac{\partial f}{\partial x} \delta_x$$

This idea can be generalized to multidimensional space.

relativeerror = expectederror / coolingwatts

$$\frac{\sqrt{\text{mdot}^2\,(-\text{Tin}+\text{Tout})^2\,\delta\text{cp}^2 + \text{cp}^2\,(-\text{Tin}+\text{Tout})^2\,\delta\text{mdot}^2 + \text{cp}^2\,\text{mdot}^2\,\delta\text{Tin}^2 + \text{cp}^2\,\text{mdot}^2\,\delta\text{Tout}^2}}{\text{cp}\,\text{mdot}\,(-\text{Tin}+\text{Tout})}$$

Pipe flow "error"

To compute the Fanning friction factor from the measurements from a pipe flow experiment, the formula is

friction = **dp** / **L d** / **ρ** / **v^2** / **2**

Take the total differential:

frictiondiff = **Dt[friction]**

$$-\frac{d\,dp\,\delta\rho}{2\,L\,v^2\,\rho^2} + \frac{dp\,\delta d}{2\,L\,v^2\,\rho} + \frac{d\,\delta dp}{2\,L\,v^2\,\rho} - \frac{d\,dp\,\delta L}{2\,L^2\,v^2\,\rho} - \frac{d\,dp\,\delta v}{L\,v^3\,\rho}$$

expectedfrictionerror = **Sqrt[Sum[frictionerror[[i]]^2, {i, 1, 5}]]**

$$\sqrt{\frac{d^2\,dp^2\,\delta\rho^2}{4\,L^2\,v^4\,\rho^4} + \frac{dp^2\,\delta d^2}{4\,L^2\,v^4\,\rho^2} + \frac{d^2\,\delta dp^2}{4\,L^2\,v^4\,\rho^2} + \frac{d^2\,dp^2\,\delta L^2}{4\,L^4\,v^4\,\rho^2} + \frac{d^2\,dp^2\,\delta v^2}{L^2\,v^6\,\rho^2}}$$

relativefrictionerror = **expectedfrictionerror** / **friction**

$$\frac{2\,L\,v^2\,\sqrt{\frac{d^2\,dp^2\,\delta\rho^2}{4\,L^2\,v^4\,\rho^4} + \frac{dp^2\,\delta d^2}{4\,L^2\,v^4\,\rho^2} + \frac{d^2\,\delta dp^2}{4\,L^2\,v^4\,\rho^2} + \frac{d^2\,dp^2\,\delta L^2}{4\,L^4\,v^4\,\rho^2} + \frac{d^2\,dp^2\,\delta v^2}{L^2\,v^6\,\rho^2}}\;\rho}{d\,dp}$$
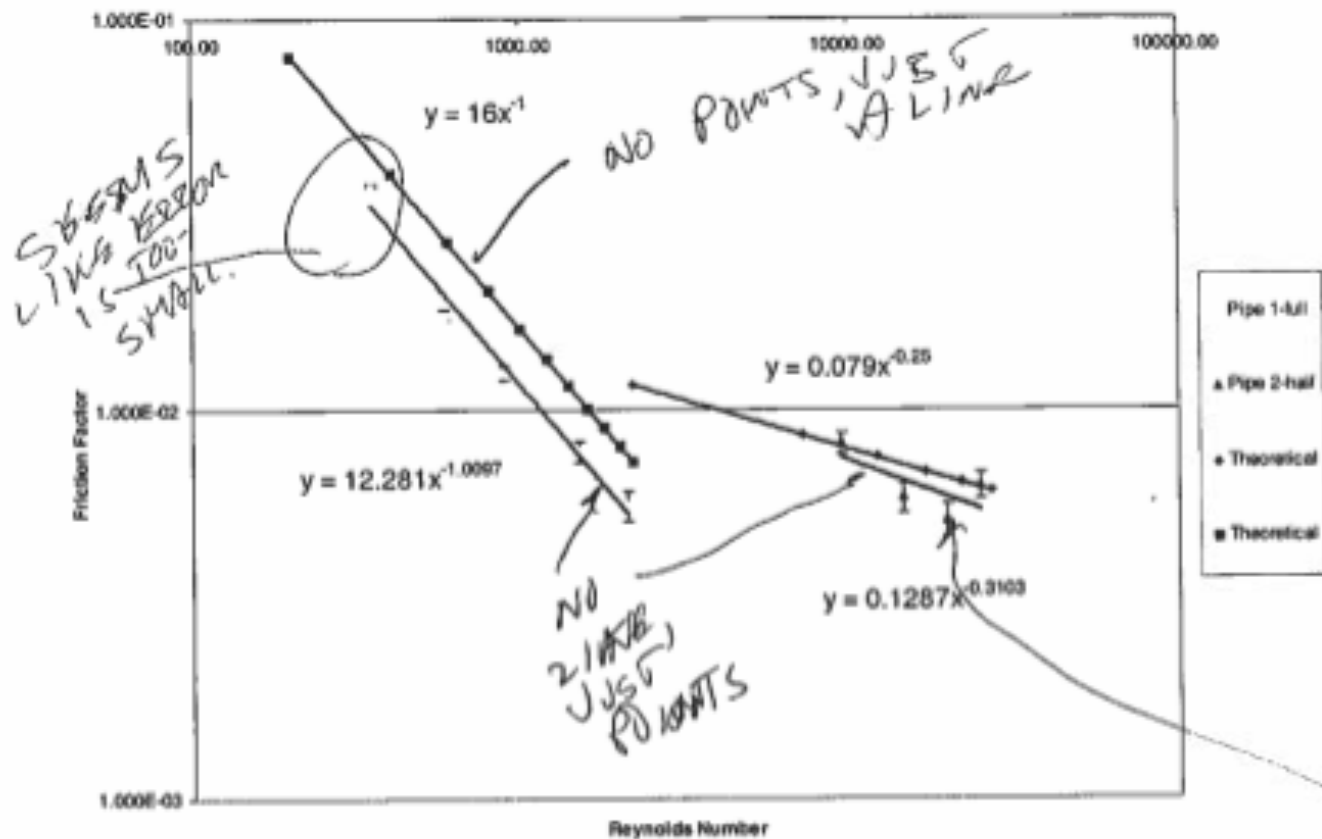
Figure 3. Laminar and turbulent flow in smooth pipes of varying diameter showing the relationship between Reynolds number and friction factor.

Discussion

8. **Discussion**

All important interpretations which follow from the results and the underlying theory are logically and quantitatively compared in the <u>Discussion</u> section. The positive conclusions, comparison with literature data, and the significance applicability, and reproducibility of the results are stressed. Quantitative statements about the accuracy and precision of the results are required. However, when a detailed error analysis is essential to the work, it should be relegated to an Appendix.

- <u>Explain</u> **what** you found out and **why** the behavior is such

  - "I", as in the instructor, want to be able to tell if you learned the fundamentals of the experiment (we get another shot at the defense!)

Discussion

- You could state that the energy balance closed to within only 80% (at best) for the heat exchanger and was best at the highest flow rates

  - Tell why, was this because of bad insulation or that your thermocouples were accurate to only +/- 1 C and the "change" in T was 4 C.

- You could note that there was +/- 20% scatter in the friction factor measurements or that these were consistently 20% low

  - explain why

- If something works well, you can explain (fundamentally) why the trend is the way it is and note that possible experimental perils did not arise

  - A critical measurement could be and was done correctly!

Conclusions

9. Conclusions and Recommendations

This section is a summary of the most significant conclusions developed in the preceding section. Quantitative statements are best. Useful recommendations to improve the experiment and to extend the work to other systems, should be included here.

Abstract

- "stand alone" document -- you do this last!

- Succinctly state the device/process/phenomenon being studied with enough quantitative information for an unconnected reader to understand what you did and what the experimental device looks like.

  - Give the analytical technique if it is important

  - Give range of parameters that were covered

- State the results quantitatively while giving context, usually in comparison with literature values or correlations

- Could give one comment on the "correctness" of your data

- Could give one statement of significance of the results in a broader sense or suggest a better way to address the problem.

Abstract as first turned in

Abstract

The purpose of this experiment is to determine the coefficient of performance of the vapor-compression cycle run on a PA-Hilton R633 Refrigeration Cycle Demonstration Unit. This number is then compared to the ideal case, or Carnot coefficient of performance, and the power supply is used to calculate the rate of refrigeration. The path of the cycles for two systems are then drawn on both P-H and T-S diagrams, and a thermodynamic analysis table is constructed for each trial.

Data is collected by varying the mass flow rates of water into the heat exchanger coils in both the condenser and the evaporator between 8 (± 2.5) g/s and 35 (±2.5) g/s. For six different trials, the water mass flow rates, pressures in the condenser and the evaporator, power input into the compressor, and the temperature at eight thermocouples around the cycle were recorded and then used to calculate the COP for each trial, ideal COP, rate of refrigeration, mass flow rate of the refrigerant, and the power supplied to the compressor.

The COPs for each trial ranged from 1.938 to 2.919, while the ideal COP ranged from 4.003 to 5.59. It was determined that when the water mass flow rates into the condenser and the evaporator were both set to high values (35 ± 2 g/s), the experimental COP was the closest to the ideal COP.

Comment [MM1]: Never start with this. Start with what being done in the device.

Comment [MM2]: This is basically a procedure, not results.

Comment [MM3]: Should be plural.

Comment [MM4]: Again, procedure

Comment [MM5]: Procedure

Comment [MM6]: Too many sig figs

Comment [MM7]: This paragraph, at least is results.

Revised by students

Revised by students:

The ideal and experimental coefficients of performance (COP), power supply, and rate of refrigeration were calculated for a vapor-compression cycle run on a PA-Hilton R633 Refrigeration Cycle Demonstration Unit (table top sized), using Solkane SES36 as the refrigerant, by varying the mass flow rates of water into the heat exchanger coils in both the condenser and the evaporator from 8 (±2.5) g/s to 35 (±2.5) g/s.

The system was found to operate best at a flow rate of 35 (±2.5) g/s with a corresponding T_{high} in the compressor of 68.3 (± 0.05) °C, T_{low} in the evaporator of 18.1 (± 0.05) °C, pressure in the condenser of 1.6 (±0.05) bar, and pressure in the evaporator of 0.4 (±0.05) bar. The ideal COP for this condition was calculated to be 4.85, while the actual was calculated to be 2.92, and the COP calculated with the actual power input reading (225 W) was 1.56.

Comment [MM1]: Now in 1 sentence we have what was done, the fluid that was used and range of operation (all that could be be varied.)

Comment [MM2]: The results: both heat exchangers need to be maxed with cooling water, when this is done I know the cold and hot temperatures and pressures.

Comment [MM3]: This sentence tells me how the device compares to ideality and how efficient it would be in terms of cooling my house or refrigerator using power input from the wall.

Some mjm edits

Revised by students and Professor

The ideal and experimental coefficients of performance (COP) and refrigeration rates were calculated for a vapor-compression cycle run on a PA-Hilton R633 Refrigeration Cycle Demonstration Unit (table-top sized), using Solkane SES36 as the refrigerant. The compressor runs at constant speed but it is possible to vary the mass flow rates of water into the heat exchanger coils in both the condenser and the evaporator from 8 (±2.5) g/s to 35 (±2.5) g/s. The input electrical power was always 215 W (+/-10). The cooling provided by the unit ranged from 180W to 350W which corresponds to external COPs of .9 to 1.6. The system was found to operate best at a flow rate of 35 (±2.5) g/s with a corresponding T_{high} in the compressor of 68.3 (± 0.05) °C, T_{low} in the evaporator of 18.1 (± 0.05) °C, pressure in the condenser of 1.6 (±0.05) bar, and pressure in the evaporator of 0.4 (±0.05) bar.

At the temperatures of the evaporator and condenser, the Carnot, Ideal COP values of would be 4-5.6. The cycle calculations using the enthalpy values were about ½ of these values ranging from 2 to 2.9. The very low external COPs were were caused by heat exchangers not providing sufficient cooling/heating to match the potential refrigerant cooling power of the constant circulation speed of the compressor.

Deleted: :

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Moved (insertion) [1]

Comment [MM2]: The results: both heat exchangers need to be maxed with cooling water, when this is done I know the cold and hot temperatures and pressures.

Moved up [1]: The system was found to operate best at a flow rate of 35 (±2.5) g/s with a corresponding T_{high} in the compressor of 68.3 (± 0.05) °C, T_{low} in the evaporator of 18.1 (± 0.05) °C, pressure in the condenser of 1.6 (±0.05) bar, and pressure in the evaporator of 0.4 (±0.05) bar.

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Comment [MM5]: I added some interpretation of the results

First time through a thought

Well, it happened again, another topic that I mentioned many times in classes that seemed to need some attention by the medical procession, has received it. Many times in the mass and energy balances class I have mentioned that I could not understand how drug dosing was done. That is, the dose for adults for almost all drugs that I have seen prescriptions for, is the same -- be it one, two, three or 4 times per day. I could not help but wonder how small women and really large men could need the same dose when a simple mass balance tells us that if it some systemic concentration of drug is needed for efficacy, then dose should scale roughly as weight. If there is partitioning of the compound in different types of tissue (e.g., fat tissue which would be hydrophobic), then perhaps a more nuanced criterion is necessary. However, in either case, all adults are not equal.

I~~Well, i~~t happened again~~, another topic that~~. I have mentioned many times in ~~classes~~ the mass and energy balance class that I could not understand how drug dosing is done. ~~that seemed to need some~~I suggested that this needed attention by the medical procession~~, has received it.~~ (as brazen as this seems!) ~~Many times in the mass and energy balances class I have mentioned that I could not understand how drug dosing was done.~~ That is, ~~the dose for~~ for all ~~-~~adults, the dose ~~s~~for almost all drugs ~~that I have seen prescriptions for~~, is the same -- be it one, two, three or 4 times per day. I could not help but wonder how small women and really large men ~~could~~would need the same dose when a simple mass balance tells us that if it some systemic concentration of the drug is needed for efficacy, then dose should scale roughly as weight. If there is partitioning of the compound in different types of tissue (e.g., fat tissue which would be hydrophobic), then perhaps a more nuanced criterion is necessary. However, in either case, all adults are not equal~~.~~ (despite the claim in the founding documents of the US!)

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Needs results

Vapor–Liquid Equilibrium of Carbon Dioxide in Aqueous Mixtures of Monoethanolamine and Methyldiethanolamine

Fang-Yuan Jou, Frederick D. Otto, and Alan E. Mather*

Department of Chemical Engineering, University of Alberta, Edmonton, Alberta, Canada T6G 2G6

Data for the distribution of carbon dioxide between the vapor and aqueous solutions of four mixtures of monoethanolamine (MEA) and methyldiethanolamine (MDEA) have been obtained at 25, 40, 80 and 120 °C over a range of pressures from 100 kPa to 20 MPa. Partial pressures of CO_2 ranged from 0.001 to 19 930 kPa. Enthalpies of reaction of CO_2 in the solutions have been calculated from the solubility data.

Several flaws

Representing Vapor−Liquid Equilibrium for an Aqueous MEA−CO$_2$ System Using the Electrolyte Nonrandom-Two-Liquid Model

Yunda Liu,* Luzheng Zhang, and Suphat Watanasiri

Aspen Technology, Inc., Ten Canal Park, Cambridge, Massachusetts 02141

Following the work of Austgen et al., the electrolyte nonrandom-two-liquid (NRTL) model was applied in a thermodynamically consistent manner to represent the vapor−liquid equilibrium (VLE) of the aqueous monoethanolamine (MEA)−CO$_2$ system with rigorous chemical equilibrium consideration. Special attention was given to the accurate VLE description of the system at both absorbing and stripping conditions relevant to most aqueous MEA absorption/stripping processes for CO$_2$ removal. The influence from chemical equilibrium constants, Henry's constant, experimental data, and data regression on the representation of the VLE of the system was discussed in detail. The equilibrium constant of the carbamate reversion reaction as well as important interaction parameters of the electrolyte NRTL model were carefully fitted to experimental data. A good agreement between the calculated values and the experimental data was achieved. Moreover, the model with newly fitted parameters was successfully applied to simulate three industrial cases for CO$_2$ removal using a rate-based approach. The results from this work were compared with those using the model by Austgen et al.

Modeling of CO$_2$ Capture by Aqueous Monoethanolamine

Stefano Freguia and Gary T. Rochelle

Dept. of Chemical Engineering, The University of Texas at Austin, Austin, TX 78712

The process for CO$_2$ removal from flue gases was modeled with RateFrac. It consists of an absorber, a stripper, and a cross heat exchanger. The solvent used in the model contains about 30 wt % monoethanolamine (MEA) in water. MEA reacts with CO$_2$ in the packed absorber. The finite reaction rate requires a kinetic characterization. The RateFrac absorber model was integrated with a FORTRAN user kinetic subroutine to make the model consistent with the interface pseudo-first-order model and with a regressed Electrolyte-NRTL equilibrium model. It was adjusted with laboratory wetted wall column data and field data from a commercial plant. Sensitivity analyses were performed on process variables to find operating conditions at low steam requirement. Many variables strongly affect the process performance, but an overall optimization shows that there are no economical ways to reduce the steam requirements by more than 10%. The reboiler duty can be reduced from that of a base case representing current industrial operating conditions, by 5% if acids are added to the solvent, by 10% if the absorber height is increased by 20%, and by 4% if the absorber is intercooled with a duty of one-third of the reboiler duty. The power plant lost work is affected by varying stripper pressure, but not significantly, so any convenient pressure can be chosen to operate the stripper.

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Good Abstract

CO$_2$ Absorption Rate and Solubility in Monoethanolamine/Piperazine/Water

Hongyi Dang (dang@che.utexas.edu)
Gary T. Rochelle* (gtr@che.utexas.edu, 512-471-7230)
The University of Texas at Austin
Department of Chemical Engineering
Austin, Texas 78712
Prepared for presentation at the First National Conference on Carbon Sequestration,
Washington, DC, May 14-17, 2001

ABSTRACT

The solubility and absorption rate of carbon dioxide into monoethanolamine/ piperazine/water were measured in a wetted wall column at 40-60°C. The total amine concentration was varied from 1.0 M to 5.0 M with monoethanolamine blends containing 0 to 1.2 M piperazine. CO$_2$ solubility and solution speciation were simulated by nine equilibrium reactions. Two of the equilibrium constants were adjusted to match literature data. The rate of absorption was predicted by the theory of diffusion with fast chemical reaction. Piperazine at 24 mol% of the total amine decreases CO$_2$ equilibrium pressure by 50% and enhances CO$_2$ absorption rate by 50% to 100%. The CO$_2$ enhancement factor decreases by an order of magnitude as loading increases from 0 to 0.5 moles CO$_2$/mole amine.

*Author to whom correspondence should be addressed

FORMATION OF WAVES ON A HORIZONTAL ERODIBLE BED OF PARTICLES

W. C. KURU, D. T. LEIGHTON and M. J. McCREADY

Department of Chemical Engineering, University of Notre Dame, Notre Dame, IN 46556, U.S.A.

Abstract—The mechanisms responsible for the initial growth of sand waves on the surface of a settled layer of particles are studied experimentally and theoretically. Experiments employ water–glycerin solutions of 1–14 cP and glass spheres ($\rho_s = 2.4\,g/cm^3$) that are either 100 or 300 μm in diameter. The particle Reynolds number and Shields parameter are of order one and the flow Reynolds number is of order 1000 to 10,000. Experimentally obtained regime maps of sand wave behavior and data on the wavelengths of the sand waves that first appear on the surface of the settled bed are presented. Turbulence in the clear liquid is not necessary for formation of waves and there is no dramatic change in behavior as the flowrate is increased across the turbulent transition. The initial wavelength varies as the Froude number to the first power. Because a flowing suspension phase is observed before waves form, linear stability analysis of the clear-layer–suspension-layer cocurrent two-phase flow is presented. The suspension phase is modeled as a continuum that has an either constant or exponentially increasing viscosity. Neither of the models correctly predicts the wavelength for the first observed waves, their growth rate or their speed. However, the initial wavelength is found to agree well with the trajectory length for a saltating particle obtained from a model for forces on individual particles.

Your experiments don't have this much to write about.
Consider the first 1/2.

Never say this!

Abstract

The purpose of this experiment was to determine the correlation between friction factors and Reynolds numbers for smooth pipes of differing diameters, a rough pipe, and a packed bed. The losses due to several fittings and valves were also studied. This was done at laminar and turbulent flow conditions using a pipe flow apparatus, rotameter and manometer. For Reynolds numbers in the range of 100-20,000, friction factors were determined to be in the range of $8*10^{-4}$ to $1*10^{-2}$ and inversely proportional to the Reynolds number for both laminar and turbulent flow. The experimentally determined friction factors were lower than the ones predicted by theory at a given Reynolds number for smooth pipes. The experimental data for the rough pipe did not correspond to theory due to error in the pressure measurement. For the packed bed, the friction factors in the laminar regime were determined to be one order of magnitude higher than those of the smooth pipe. The losses due to the fittings and valves were calculated using Bernoulli's equation. The experimental K factor for an orifice plate was 2.41, which was 12% higher than the theoretical value of 2.15.

[handwritten annotations:] WAS PERFORMING; varying (1/2, 1/2..); an orifice, a venturi, gate, globe.; HOW LOW IS; What or how did you know.; LOSSES POR VALVES F is only SCALARS u^2..

Pipe flow experiment abstract

Flow of water in 1/4, 1/2 in. (etc.) smooth pipes, a 1/2 in. rough pipe and a bed packed with 3 mm spheres, over Reynolds number ranges of 100-20000 was studied with the goal of verifying the laminar and turbulent relations between friction factor and Reynolds numbers (Re). In addition, pressure drops across an orifice, a vVenturi, a gate valve and a globe valve were also measured to determine if the the losses follow the expected velocity-squared behavior. Laminar flow occurred only in the 1/4 in,. pipe and only 4 data points obtained. These friction factors were consistently 20% high, but the trend was consistent (within experimental error) with the expected inverse reaction with Re. The friction factor data for turbulent flow did not collapse onto a single relation with the data from the smaller pipes (1/4, 3/8 in) being 15% above the Blassius relation and the largest pipe (3/4 in) about 10% below. However the variation with Reynolds number agreed with the -.25 power of Reynolds number. For the packed bed, only the laminar region was accessible; the friction factor data displayed the expected inverse relation with Reynolds number but the numerical values were 30% high. AFor all of the fittings showed good agreement with the pressure varyinged with the square of the velocity. As expected, the coefficient for the Venturi was close to one (.98); the value for the orifice (for which the area ratio was 0.7), was 0.6, also consistent with expected values.

- I might have mentioned that we used pressure transducers,

Abstract

This experiment analyzed the diffusion of gaseous CO_2 into a liquid of Stoddard Solvent at 1 atmosphere of pressure with temperatures of 25, 30 and 35°C. The variables determined at these conditions were the solubility, diffusion coefficient, and the enthalpy of solution. The CO_2 was measured and delivered by a gas detector to a sealed cell containing Stoddard Solvent via a pipe and valve system. This airtight system allowed for the determination of the moles of CO_2 delivered to the cell of Stoddard Solvent at a given time. Using a molecule penetration theory derived by Higbie, mathematics based on the diffusion theory of molecules, and this data the diffusion coefficient was calculated. The average diffusion coefficient was $4.918*10^{-3}$ [cm^2/s] $\pm 1.57*10^{-4}$ at 25°C, $4.692*10^{-3}$ [cm^2/s] $\pm 1.33*10^{-4}$ at 30°C, and $6.555*10^{-3}$ [cm^2/s] $\pm 1.25*10^{-4}$ at 35°C. These were generally high by about two orders of magnitude when compared to the literature value of $2.11*10^{-5}$ [cm^2/s] (298 K, 1 atm). In order to quantify this significant source of error, one trial excluded the use of a bath stirrer. However, the calculated diffusion coefficient for that trial was found to be comparable to the other trials. It was concluded that the bath stirrer did not contribute significantly to the error, and must have been caused by either the vibration of the lab as a whole or from the convection of the CO_2 gas. The solubility was calculated by measuring the total moles that would dissolve in the Stoddard Solution. The average solubility was $6.197*10^{-5}$ [mol/cm^3] $\pm 2.71*10^{-7}$ at 25°C, $5.963*10^{-5}$ [mol/cm^3] $\pm 2.81*10^{-7}$ at 30°C, and $5.549*10^{-5}$ [mol/cm^3] $\pm 2.81*10^{-7}$ at 35°C. These calculations were comparable to the solubility of CO_2 in n-pentane (a similar hydrocarbon molecule): $8.206*10^{-5}$ [mol/cm^3]. The heat of solution was calculated through the use of Henry's Law, which assumed that the CO_2 was greatly diluted in the solution, and an equation derived from the Gibbs-Helmholtz Equation. This derived equation allowed for the calculation of the heat of solution because it related the Henry's Law constant with the temperature. The temperature was known and the Henry's Law constant was calculated through the solubility and fugacity of the CO_2 gas. The heat of solution was determined to be -8856.395 [Joule/mole] ± 651.465. This experiment may be improved in the future by making slight changes in the

References

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