Engineering Ethics Cases with Numerical Problems

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Chemical Engineering Case 3

Marginal Environmental Returns

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Suggested Courses:

Mass and Energy Balances, Thermodynamics

Level:

Sophomore & Junior

Narrative

Joe has been working with the Polymers-Are-Us Chemicals (PAU Chemicals) for almost 15 years. For most of this time, he's been working as an environmental engineer for the company, reporting to state and national regulators during inspections and maintaining records of the company's pollution and wastewater treatment procedures.

Because he has worked so long in the department, Joe has become acquainted with many of the state regulators and board members personally, and they trust Joe to provide them with accurate information concerning the company's waste production. As a rule, PAU Chemicals has always met the state regulations for water quality control, and Joe has always been very cooperative with the inspection teams from the state.

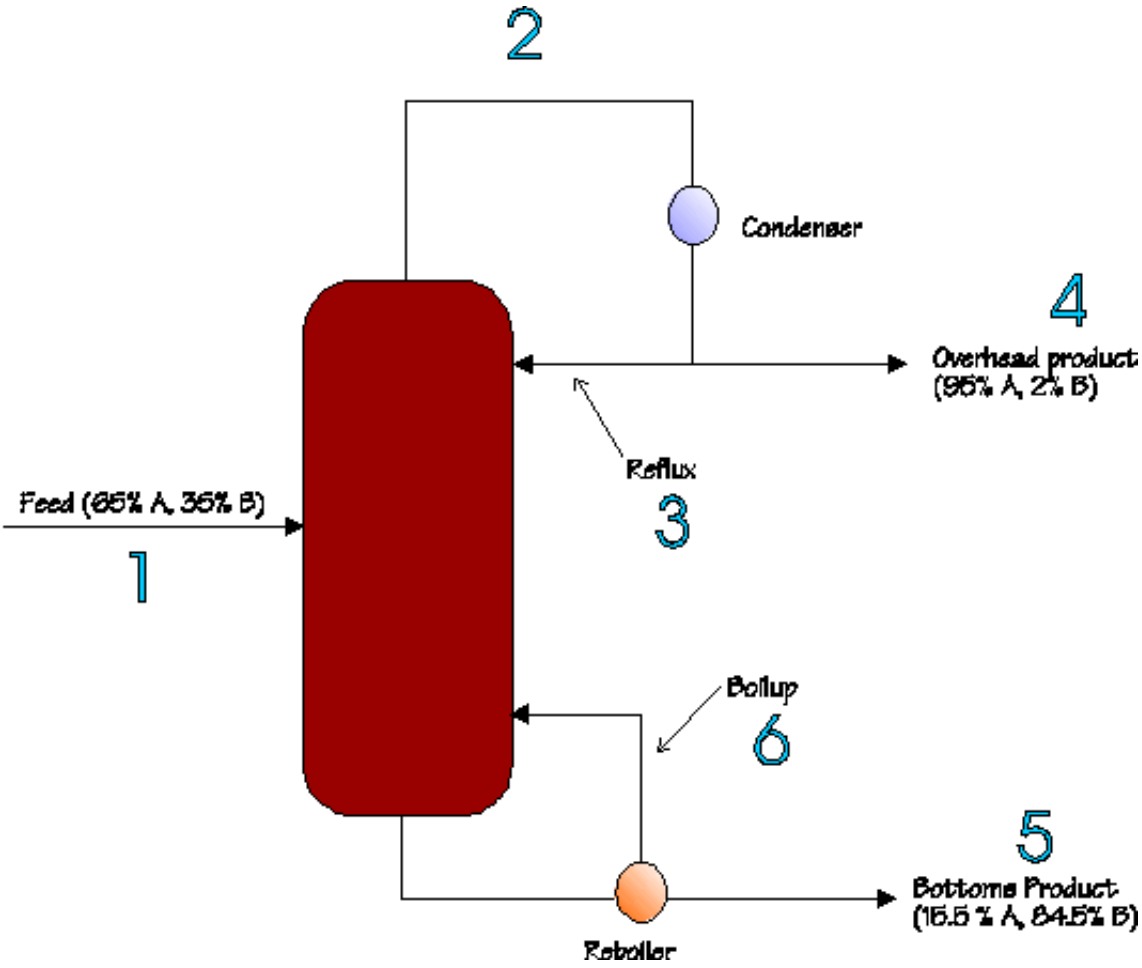
In recent years, Joe has noticed that even when the company is operating just below the environmental standards set by the state, there have been significant environmental problems downstream of the plant outflow. Problems include declining plant life, and periodic "fish kills." The river isn't used commercially except by PAU Chemicals as a waste stream release. Few people use this segment of the river, except a rare water skier or an even rarer fisherman.

After studying the problem, Joe believes that the state regulations are not restrictive enough and that the company should install another distillation column, which would lower the plant waste output to a safer level. Joe plans to

approach management with a proposal at the next engineering meeting.

Numerical Problem

1. A mixture containing 65 mole % A and the balance B is separated in a continuous distillation column at 1 atm. A flowchart for the operation follows.



The overhead stream from the column is a vapor that passes through a condenser. The condensed liquid is divided into two equal streams: one is taken off as the overhead product and the other (the reflux) is returned to the column. The bottom stream from the column is a liquid that is partially vaporized in a reboiler. The liquid stream emerging from the reboiler is taken off as the bottoms product, and the vapor is returned to the column as boilup. Negligible heat is lost from the column, so that the only places in the system where external heat transfer takes place are the condenser and the reboiler.

Stream Composition Data

Feed - 1: Liquid, 65.0C; 65 mole%A, 35%B

Overhead - 2: Vapor, 63.0C; 98 mole%A, 2%B

Distillate - 3: Liquid, 56.8C; 98 mole%A, 2%B

Reflux - 4: Liquid, 56.8C; 98 mole%A, 2%B

Bottoms - 5: Liquid, 98.7C; 15.5 mole%A, 84.5%B

Boilup - 6: Vapor, 98.7C; 54.4 mole%A, 45.6%B

Thermodynamic Data *H*(cal/mol)

(here, *H* is specific enthalpy)

	A (1 atm)		B (1atm)	
T(C)	H_l	H_v	H_l	H_v
56.8	0	7205	0	5723
63.0	205	7322	194	6807
67.5	354	7403	335	6884
98.7	1385	7946	1312	7420

(a) Taking 100 mol feed as a basis, calculate the net heating requirement (cal) for the process. You may neglect heats of mixing.

(b) For the same basis, calculate the required heat input to the reboiler and the required heat removal from the condenser.

(c) Scale up the process assuming a process feed to the distillation column of 35,000lb_m/week, and an average molecular weight of 146 g/mol for both compounds. What is the mass of dissolved waste (A) is being dumped into the river?

Note: The state limit is 40,000 lb_m/week A (found in the output of the Bottoms product, not counting the Overhead product. Assumed that the A rich compound is recycled back into the process before the distillation columns).

Ethical Question

1. The management team agrees with Joe's analysis of the distillation column, but is adamant that they do not need to add another column as long as they are already below the state regulations. Joe feels strongly that PAU Chemicals has a greater responsibility to the environment and that the state regulations are not low enough. His immediate supervisor, Tom Terry, asks to speak with Joe in private after the meeting about his concerns. What should Joe say to convince Tom of the need to install a new distillation column? How could he justify going beyond the bounds of what is required by the state regulations? Is there a creative-middle-way approach between doing nothing and adding another column? Are there several such solutions? Should Joe promote them? Explain.**Narrative (Continued)**

During routine maintenance of a reactor vessel at your sister plant, technicians find an irreparable crack in the vessel wall. The plant cannot continue to operate until the vessel is replaced and must be shut down for an

indefinite amount of time (at least one month).

PAU Chemicals has just signed a new contract for their product with a very large corporation. The corporation has promised larger contracts in the future if they are satisfied with PAU's work on this contract. If the company wants to stay on schedule to keep up with the contract, Joe's plant will have to almost double its production rate. An increase of this size will have a corresponding increase in pollution into the river.

Joe receives a call from the plant manager, Vince Welling, asking to meet with him that afternoon. During the meeting, Vince tells Joe that the plant will be running at an increased rate and will probably run over the state limits for pollution. Joe knows that an increase like Vince is suggesting means the possibility of very heavy fines, and that the plant is already putting out far too much pollution for the river environment to handle. Vince tells Joe that he has to let the management know when the state plans to visit so that they can hold-up the waste for longer than normal in their temporary storage ponds before decanting it into the river. That way they can maintain constant production even while the inspection is going on, and just dump the waste later after the inspection.

Joe reminds him of his earlier presentation which indicates that the river can't handle these levels of pollution and that more distillation columns are going to have to be added to handle the higher load. But Vince tells Joe, "It's only temporary, and we'll put another column or two in after we get this contract. You just let us know when we need to slow down and don't leave a paper trail for them to follow. Let your managers take care of the production decisions."

Numerical Problems

1. Assuming an increase of 200% in the waste stream being fed to the distillation columns, design a computer program that will calculate how many more columns must be added in order to cut the waste down to less than 1 lb_m/week.

2. Assume that the pollutant concentration can be measured as a single variable C_A (moles/volume). Making other assumptions as appropriate, derive the differential equation dynamic model for pollutant in the river as a function of position and time. You may consider that the pollutant decays naturally in a first order chemical reaction.

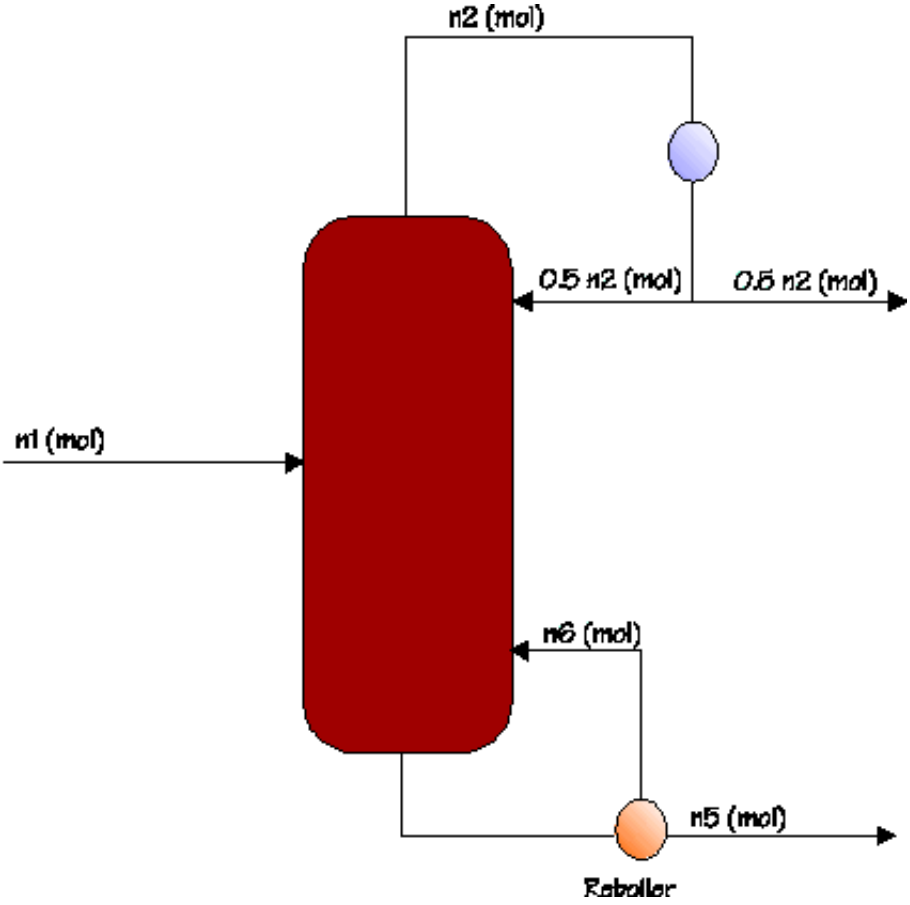
3. The cost of adding a distillation column is $10,000 per column, and the cost of energy is $\$1/10^6$ Btu. The mass of waste removed by each column decreases as another column is added. Plot the total cost of the columns added versus the total amount of waste removed (in lb_m).

Ethical Questions

1. There are several models of professional responsibility. The Malpractice Model requires engineers to avoid charges of malpractice or breaking the law, and to avoid actions that will directly harm. The Due-Care Model requires engineers to take a proactive stance that actively seeks to prevent foreseen or anticipated harm. The Good Works Model requires engineers to go beyond the Due-Care Model in preventing harm and promoting the public good, even at considerable personal inconvenience to the engineer. Which model best describes Joe's recommendation to install another distillation column? Do you think professional obligation requires Joe to make this recommendation? What tactic should Joe use in making his recommendations to management, whatever they are?

1. Suppose Joe follows Vince's instructions and reports plant emissions at the time the inspectors are there and not at the time the plant is emptying the waste held in the storage facilities. (1) What is lying? (2) Is this a case of lying? (3) If it is lying, is it justified?
2. **Solutions to Numerical Problems**

1. Distillation Column Computations



a) Overall Balances:

Total Moles = 100 = 0.5 n_2 + n_5

A = 0.65 (100) =0.98(0.5 n_2) + 0.155 n_5

n_2=120 mol n_5= 40 mol

Product Flow Rates: Overhead: 0.5(120)(0.98) = 58.8 mol A

0.5(120)(0.02) = 1.2 mol B

Bottoms: 0.155(40) = 6.2 mol A

0.845(40) = 33.8 mol B

Overall Energy Balance: $Q = H = (out)\ n_iH_i - (in)\ n_iH_i$

$Q = 58.8(0) + 1.2\ (0) + 6.2(1385) + 33.8(1812) - 65(271) - 35(257) = 2.63x10^4$ cal

b) Flow Through Condenser: 2(58.8) = 117.6 mols A

2(1.2) = 2.4 mols B

Energy Balance on Condenser: $Q_c = H$

$Q_c = 117.6(0-7322) + 2.4(0-6807) = -8.77x10^5$ cal heat removed from condenser

Assume negligible heat transfer between system and surroundings other than Q_c and Q_r.

$Q_r = Q - Q_c = 2.63x10^4 - (-8.77x10^5) = 9.03x10^5$ cal heat added to the reboiler.

2. Calculate scale-up for feed stream (factor of increase) and multiply by the bottom tails stream. Take the percentage of the bottom tails stream that is A to find your amount deposited into the stream. The conversion from grams to lb_m is 2.20462 lb_m/1000g.

3. Using Fortran or any spreadsheet program, repeat iterations of the distillation process until the bottoms content of A is less than the desired amount. If not, then use the bottoms tails composition as your feed into a second distilling compound. Add another $10,000 for each column added, and sum the lb_m A in the overhead stream for each process iteration. Use these two summations for your plot in number 5.

4. Proof of differential equation of dynamic stream model.

Assumptions: River has a constant cross-section A_x

River has a constant velocity V

No axial dispersion (concentration varies only up and down stream)

Single Concentration Matters - C_A

Pollutant Decays as first order chemical reaction

[Rate of Change of Pollution Element] = Bulk Flow In - Bulk Flow Out

+Diffusion In - Diffusion Out

- Decay

Pollutant in Element = $C_A A_{xX}$

Diffusive Flux = - D(C/X) (moles/(area*time))

Therefore $\mathbf{d(C_A A_x X)/dt = (VA_x C_A - DA_x(C_A/X))_x}$

$\mathbf{- (VA_x C_A - DA_x(C_A/X))_{X+X} - k(A_x X)C_A}$

AND

$\mathbf{(A_x X)d(C_A)/dt = (VA_x C_A - DA_x(C_A/X))_x - (VA_x C_A - DA_x(C_A/X))_{X+X}}$

$\mathbf{- k(A_x X)C_A}$

Therefore

(1) $\mathbf{d(C_A)/dt = ((VC_{Ax} - VC_A x+x)/x)}$

$\mathbf{- ((D(C_A/X)_x - D(C_A/X)_{x+x})/ x) -kC_A}$

By Definition $\mathbf{df/dx = lim(x0)\ (f(x+x) - f(x))/ x}$ therefor, take the limit of (1) and

$\mathbf{(C_A)/t = -V(C_A/x) + D(^2C_A/x^2) - kC_A}$

Ethical Solutions (Or Recommended Paths of Thinking)

1. Joe's recommendation does not fit the Malpractice Model, because the plant is not breaking the law. His action is best described by either the Due-Care Model or the Good Works Model, depending on such factors as how severe the environmental problems downstream are, whether the plant can easily afford the new distillation column, how much Joe is risking his job by making the recommendation, how likely it is that the state regulations will be changed and how likely it is that human life could be endangered. As with many ethical problems, we cannot answer the question adequately without additional knowledge of the facts.

In the absence of factual knowledge, however, we can make assumptions. Suppose we assume that the environmental damage is considerable but that human life or health is not threatened, that the plant can afford the new distillation column and will probably eventually be required to install it and that Joe's job will not be threatened by any recommendation he makes. In this case, Joe's recommendation to install another distillation column falls under the Due-Care Model.

Whether Joe should make this recommendation depends on what model of professional responsibility you believe he should follow. In general, the Due-Care Model seems to be the most appropriate. Most professional codes, such as the code of the National Society of Professional Engineers (NSPE), require engineers to "hold paramount the safety, health and welfare of the public in the performance of their professional duties." This seems to involve more than simply avoiding action that breaks the law or provokes charges of malpractice. This seems to imply the Due-Care Model.

The code, however, refers to human health, and we have assumed that there is no threat to human health. So the question is what holding paramount public "welfare" means in this situation. The term is not defined in the code but has been interpreted by the NSPE's Board of Ethical Review in case 85-2 as requiring engineers to try to get designs in a defense project modified in order to save tax dollars. Might it also require an engineer to at least recommend measures that would prevent substantial environmental harm, assuming that this environmental harm

would adversely affect public welfare? If it does, Joe has an obligation to recommend that another distillation tower be installed.

If we conclude that Joe should recommend that another distillation tower be installed, there is still a question how the recommendation should be made. When dealing with business management, the best approach may not be trying to prove that cutting back to pollution is good for public welfare, but that it is good for business. Joe should try to convince his manager that cleaning up the river would give the firm good publicity and that it probably would eventually be required anyhow.

2. (1) We can define a lie as a statement believed to be false or seriously misleading,

made with the intention to deceive.

(2) Whether Joe lies to government officials depends, of course, on what he says. Suppose he says to officials while they are making their inspection of the plant, "The present emissions from our plant are never exceeded." Then he would be lying, because the emissions are exceeded when the excess from the storage tanks is dumped. Joe might avoid outright lying by refusing to make such statements.

There are however, other types of misrepresentation of the facts besides outright lying. He might, for example engage in deliberate deception, withhold information, or simply fail to inform regulators of all of the facts about the plant. If he follows Vince's instructions, it would probably be impossible for Joe to avoid misrepresentation in one of these senses, even if he were not to tell a lie. We could certainly consider all of these types of misrepresentation as types of dishonesty.

(3) Professional codes have a great deal to say about dishonesty. For example, section II, 3, a of the code of the National Society of Professional Engineers (NSPE) reads: "Engineers shall be objective and truthful in professional reports, statements or testimony. They shall include all relevant and pertinent information in such reports, statements or testimony." This provision speaks directly to Joe's situation and suggests that withholding information from government officials would be wrong.

There is, furthermore, good reason for the insistence on honesty in the engineering codes. What engineers (or other professionals) have to offer the public is expert knowledge and judgment. If professional knowledge and judgment are corrupted by dishonesty, the value of professional services is undermined. Therefore, the strong emphasis on honesty in the codes is fully justified. So complying with Vince's instruction is a violation of professional standards and unjustifiable.