ORDRE DES INGÉNIEURS DU QUÉBEC

MAY 2017 SESSION

Open-book examination
Calculators : only authorized models
Duration : 3 hours

16-CH-A5 Chemical Plant Design and Economics

PROBLEM 1 - (10 points)

COST STUDY ACCURACIES

As a cost engineer for a consulting engineering firm, a customer wants to give you a mandate to perform a detailed cost estimate (contractor's estimate) of a project, of around 10 million dollars (order-of-magnitude estimate). He wants to save time and avoid to realise preliminary engineering and cost estimation, and to get an accuracy of ± 5% on project cost estimation. The customer propose to give you 100 000$ to perform the study. Do you accept this mandate ? Explain your reasons.

PROBLEM 2 - (15 points)

YOU HAVE WON THE JACKPOT !

You have won the lottery of 20 millions ! A contractor meets you to submit to you his investment project to double you capital in four years. His project consists in a new revolutionary product, which needs more than 15 millions dollars in process equipment. He pretends that with your 20 millions dollars, he could erected a new plant and that the net rate of return on investment will be higher than 50%. Using the common rules of thumb to get an order-of-magnitude cost estimation based on equipment cost, what is abnormal in the contractor fixed capital cost estimation? Assume that this is a purely fluid chemical process.

PROBLEM 3 - (25 points)

HEAT RECOVERY FROM WOOD CHPIS DRYER

An oriented strand board panel plant wants to evaluate the profitability to recover latent heat of waste steam coming from the stack of a wood chips dryer. The gases coming from the stack are a mix of hot air and steam coming from wet chips drying. A consultant recommends to the plant the use of a spray tower as a direct contact condenser to recover the heat content of exhaust gases, using warm water to produce hot water, following the process sketch given in figure 1.

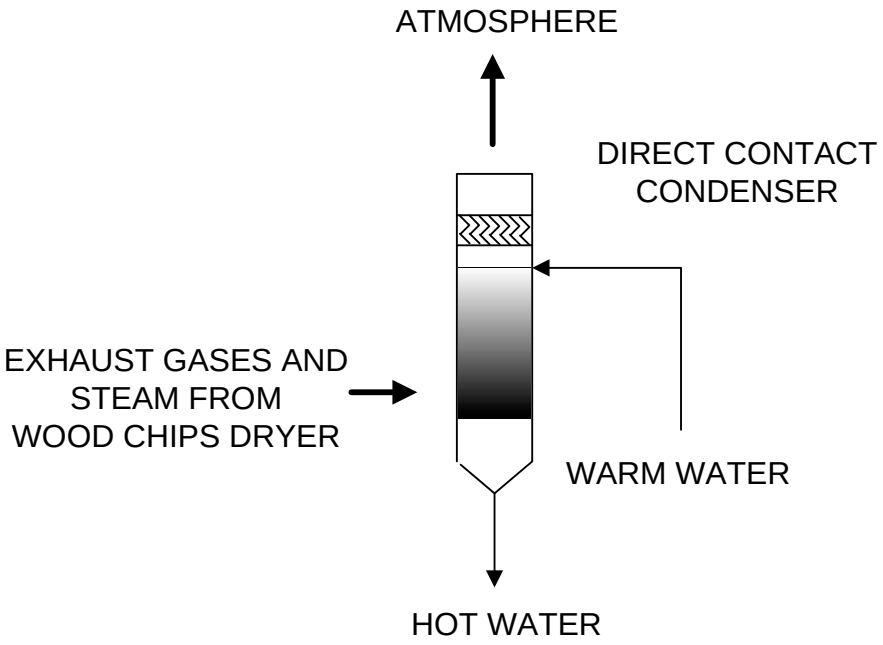

Figure 1- Heat recovery system from wood chips dryer.

We will assume that :

i) The only piece of equipment is the spray tower, which will act as the direct contact condenser.
ii) We will suppose that the major heat recovered is latent heat of steam
iii) The cost of spray tower is 315 000$, delivered at the plant.
iv) The mass flow of steam condensed is 50 000 lbs/hour.

a) Using a factorial (order-of-magnitude) cost estimation approach, what would be the total capital investment of this project?

b) Assuming 4$/Million BTU of heat recovered in hot water, and negligible operating cost of the system, what would be the gross rate of return of this project?

c) What will be the payback of this project?

Others assumptions: system uptime will be 8 400 hours/year, process is fluid and latent heat of steam is around 1 000 BTU/lb.

PROBLEM 4 - (40 points)

MOTOR SIZING OF A CENTRIFUGAL PUMP

We ask you to size a pipe, in order to transfer 5000 USGPM of water to feed a reactor located 100 m from the pump location, 4 m above the water tank level and at the reactor pressure of 15 psig (see figure 2). However, your boss has found an existing pump that he wants to reuse if its specifications match with project needs. On the pump nameplate, we can read : « Design Flow : 5 000 USGPM », « Motor Power : 100 kW » and « Mechanical Efficiency 85% ». Unfortunately, the pump head (total discharge head) cannot be read, because the nameplate is old, and the pump documentation was lost.

a) What is the optimum pipe diameter that you propose at the pump outlet, using rules of thumb (typical water velocity) ?

b) What will be the approximate discharge pressure at the pump outlet, knowing that the friction losses are around 2 feet of water column for every 100 ft of pipe ?

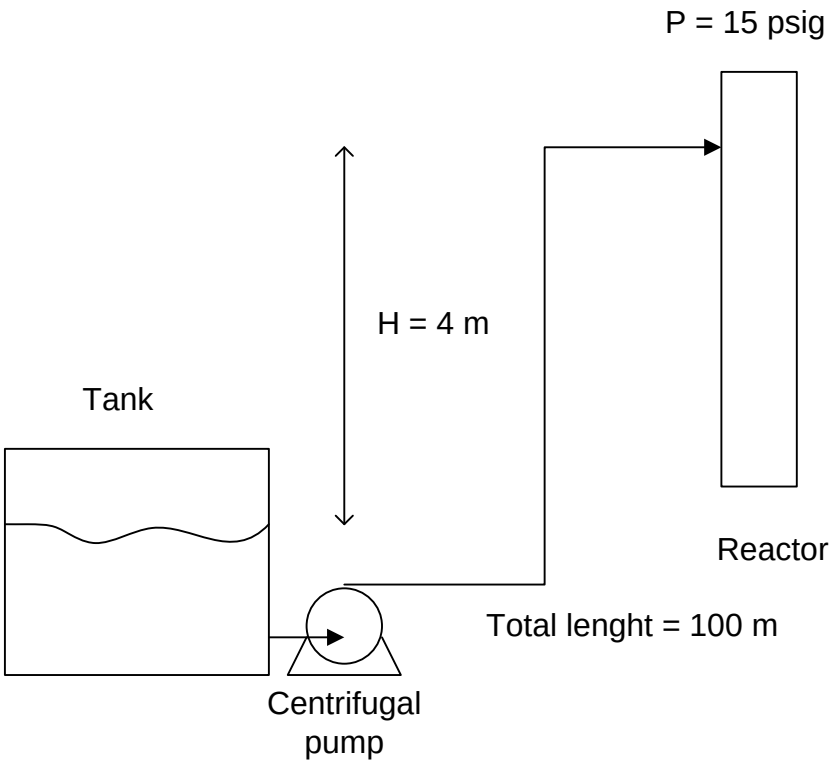

Figure 2- Alimentation en eau d'un réacteur.

c) Based on pump motor power, do you think that the existing pump may be reused ?

We may assume 90% for motor electrical efficiency. Explain your answer.

d) Based on your previous calculations, what will be the annual power losses, in terms of dollars per year, for an operation of 8 400 hours per year at 0.05$/kWh ?

e) Assuming that a new pump will cost 30 000$, do you think that is a good idea to reuse the existing pump if the expected project life is 10 years ?

Note : 7.48 USG = 1 cubic foot, 101.3 kPa = 14.696 psig, g=9.81 m/s^2
water specific weight=1000 kg/m^3

PROBLEM 5 - (10 points)

SHELL AND TUBES HEAT EXCHANGER COST ESTIMATION

In a recent project (January 2017), you obtain a quotation for a tubular exchanger, made of stainless steel tubes and carbon steel shell. The purchasing equipment price was 75 000$ for a heat exchange area of 1000 ft^2.

We ask you to estimate the cost for an exchanger of 3000 ft^2 with all others specifications remaining the same, for this afternoon 15:00 PM. Therefore, you don't have the time to get a new quotation.

a) Using the rule of thumb relating purchase equipment costs and size for process equipment, what may be the cost of the exchanger ?

b) Assuming that your preliminary sizing of 3000 ft^2 is accurate at ±30%, which error it may causes on your cost estimation in a) ? Explain.