ORDRE DES INGÉNIEURS DU QUÉBEC

NOVEMBER 2017 SESSION

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

16-CH-A5 Chemical Plant Design and Economics

PROBLEM 1 - (25 points)

NEW CEMENT PLANT

You read the newspaper announcing the construction of a new cement plant. According to the newspaper article, the cost of the project's total capital investment would be $ 1.0 billion. Assuming that the rate of return on investment (ROI) of the project would be 20% and sales are $ 600 million per year :

a) What would be the total annual production cost of this project?

b) The newspaper indicates that the project was financed by a loan of $ 600 million over 15 years at the interest rate of 6%. What would then be the *annual financing (interest) costs* on this loan, assuming that it is repaid by equal annual payments?

c) According to the usual rules of thumb for factorial analysis of chemical plant construction costs, what could be the *purchased equipment cost* of this project (this is a solid process)?

Note: It will be assumed that the working capital is 15% of the total capital investment of the project.

PROBLEM 2 - (10 points)

ESTIMATION OF DETAILED ENGINEERING COSTS

A project consists to build an acetone plant will cost more than $ 50 million. Based on the typical percentages (cost factors) of fixed-capital investment

costs for chemical plants in general, what could be the costs of detailed engineering and supervision for the project?

PROBLEM 3 - (25 points)

SUBSTITUTION OF NATURAL GAS BY BIOMASS

A plant is evaluating the possibility of purchasing a new biomass boiler to replace an existing natural gas boiler to produce the steam required for a chemical process. The required amount of steam would be 100 000 lbs / hr.

a) What would be the annual amount of biomass needed to produce this amount of steam?

The simplified basic data are:

Steam internal energy: 1 000 BTU/lb of produced steam
Plant up time: 8 400 operating hours/year
Boiler overall efficiency: 66.7% (steam energy output/fuel energy input)
Biomass heat of combustion: 20 GJ/metric ton of biomass
Conversion factor: 947.8 BTU / MJ

b) Assuming that the cost of natural gas is $ 3/million BTU and that of the biomass of $ 2/million BTU, what would be the annual fuel cost reduction ?

c) If the cost of the new boiler is $ 20 million, and the plant wants a rate of return on investment (ROI) of 10%, would that project be accepted ?

PROBLEM 4 - (20 points)

REUSE OF AN EXISTING FAN

Your boss ask you to size a fan to transfer 50 000 SCFM (standard cubic feet per minute) of air to ventilate a building to 500 ft from the intended location of the fan. However, your boss has found an old fan and would like to reuse it if its specifications are compatible with the project need. The identification plate shows: "Design Flow: 50 000 SCFM" and "Motor Power: 50 kW". Unfortunately, the value of the static pressure is unreadable because the identification plate is worn out, and the documentation of the equipment has been lost.

a) Assuming that the friction loss in the pipe is one inch of water column (1 "W.C.), what would be the required power of the fan?

NB: At this stage of estimation, 65% and 90% will be assumed for the mechanical efficiency of the fan and electric motor, respectively.

b) Based on your previous calculations, what is the annual amount of money wasted in power at 8 400 h / year and at 0.05 $ / kWh?

c) Knowing that a new fan would cost $ 25 000, what do you recommend to your boss, if the economic horizon of the project is at least 10 years?

PROBLEM 5 - (20 points)

SIZING AND COSTS ESTIMATE OF A TUBULAR EXCHANGER

As part of a project, you are asked to preliminary size a shell and tube heat exchanger. The application consists of a one pass shell side and a one pass tube-side exchanger. The vapors to be condensed would be located in the tubes, while the cooling water would be countercurrent on the shell side. The warm water would be at 100 °F and we would like to obtain hot water at 160 °F. The vapors would be at an average temperature of 212 °F and the vapor load at the condenser inlet of 10 000 lbs / h. Latent heat of vapor will be taken as 1000 BTU / lbs for condensation. The overall heat transfer coefficient for the application would be 250 BTU / h / ft^2 / °F.

(a) Estimate the amount of required cooling water, using 1 BTU / lb / °F for the heat capacity for water.

b) Based on the definition of the overall heat exchange coefficient and the assumption that all steam is condensed, estimate the heat exchange area of the tubular exchanger.

(c) The price for an exchanger with the same specifications is $ 75 000 for an exchange surface area of 1000 ft^2. Based on rules of thumb relating purchased equipment costs to the critical size of process equipment, estimate the cost of the heat exchanger.