BBL732: Bioprocess Plant Design
Minor Examination

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9th November, 2020
15.30 – 17.30 Hrs.

Answer all questions. Maximum marks 30

1. The process technology available for production of product P is as follows:
   Batch fermentation of the complex medium is carried out at a temperature of 30^{o}C. From inoculation to harvesting, the fermentation takes 24 hours. The fermented broth will have 4% (w/v) P and 3% (w/v) biomass. P is an extra-cellular product and is miscible with water in all proportions. The fermented broth could be clarified in a settler such that the settler overflow has 0.5% (w/v) biomass and the underflow, 30% (w/v) biomass. The settler overflow stream can be filtered using a rotary vacuum filter such that the filtrate is free of biomass and the cake has 98% (w/v) biomass. The clarifier underflow may be further processed using a continuous bowl centrifuge to result in a biomass-free supernatant and a thickened slurry having 98% (w/v) biomass. The biomass-free streams are then subjected to continuous distillation. It is known that if the vapors coming out at the top of the distillation column are completely condensed and a reflux ratio of 8.0 is used, 36 ideal stages are required to result in a product stream at 30^{o}C containing 90% (w/v) P and a bottom stream, at 100^{o}C, containing 0.4% (w/v) P, which is normally rejected. Normally, the overall efficiency of the bubble-cap trays does not exceed 60%. The product stream could be further purified to 99.8% (w/v) P using a membrane process, resulting in a waste stream containing 0.1% (w/v) P.
   Densities of biomass, P and water may be taken as 1000 kg.m^{-3}.

   Dry, saturated steam is available at 25 psi(g).

   Cooling water is available at 25^{o}C.

   Heat capacities of P and water are 2.5 and 4.0 kJ.(kg.^{o}K)$^{-1}$ respectively.

   Boiling point of 90% P and water mixture is 60^{o}C.

   Latent heats of P and water at 60^{o}C are 700 and 2200 kJ.kg^{-1} respectively.

   Latent heat of condensing steam is 2800 kJ.kg^{-1}

   Rise in temperature of cooling water is 5 ^{o}C.

   Calculate the steam and cooling water requirement per day for a plant producing

   10000 kg. d^{-1} of 99.8% pure P.

   (12 marks)

2. The bioreactor to be used in a process plant is a vertical, cylindrical vessel of total volume 40,000 litres and a height-to-diameter ratio of approximately 1.4. This vessel is to be used at a maximum internal pressure of 20 $kg.cm^{-2}$ as well as a vacuum of 10 $kg.cm^{-2}$. The vessel has tori-spherical closures at the top and bottom, which together weigh about 15% of the weight of the shell. The impeller, impeller shaft and motor together will weigh about 5% of the weight of the shell. The liquids normally handled in this vessel will have a specific gravity in the range of 1.0 – 1.2**.** The reactor vessel will have an expected life of 12 years, after which it may be scrapped, as per the existing rules on depreciation and book-keeping.

   Estimate the minimum thickness required for the shell, which is made of either carbon steel or stainless steel.

   Permissible stress for stainless steel = 1200 $kg.cm^{-2}$

   Permissible stress for carbon steel = 900 $kg.cm^{-2}$

   Specific gravity of steels = 7.5

   Modulus of elasticity of steels = $30x10^6$ psi (2.1$kg.cm^{-2}$)

   Poisson's ratio for steels = 0.3

   The material being handled in the reactor results in an annual corrosion of 0.004 i.p.y in carbon steel and 0.001 i.p.y in stainless steel.

   (18 marks)