NATIONAL EXAMINATIONS DECEMBER 2011

07-Mec-A1 Applied Thermodynamics and Heat Transfer

3 Hours Duration

Notes :

1. If doubt exists concerning the interpretation of any question, the candidate is urged to make assumptions and clearly explain what has been assumed along with the answer to the question.

2. The examination is open book. As a consequence, candidates are permitted to make use of any textbooks, references or notes.

3. Any non-communicating calculator is permitted. However, candidates must indicate the type of calculator(s) that they have used by writing the name and model designation of the calculator(s) on the inside of the cover of the first examination book.

4. It is expected that each candidate will have copies of both a thermodynamics text and a heat transfer text in order to make use of the information presented in the tables and graphs contained.

5. The answers to five questions, either three questions from Part A and two questions from Part B or two questions from Part A and three questions from Part B, comprise a complete examination.

6. Candidates must indicate the answers that they wish to have graded on the cover of the first examination book. Otherwise the answers will be graded in the order in which they appear in the examination book(s) up to a maximum of three answers per section .

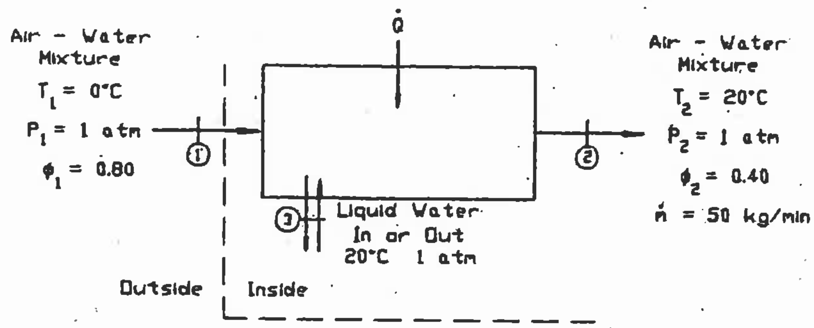
7. The answer to any question carries the same value in the grading .

Continued on Page 2

PART A - THERMODYNAMICS

1. A perfectly insulated 0.5 m^3 tank contains air at 7.0 MPa and 250°C. A valve on the tank is opened and air is discharged until the pressure drops to 400 kPa. Determine the mass of the air that has been discharged and the loss in internal energy accompanying the process.

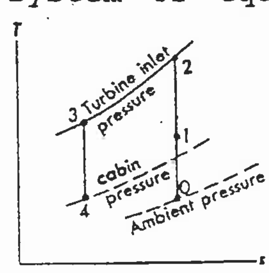
2. The unit depicted in the accompanying diagram is intended to be used to heat a building in the winter according to the conditions specified.



(a) Determine the rate in kg/min at which water must be added or withdrawn from the mixture and (b) Calculate the rate of heat transfer in kW.

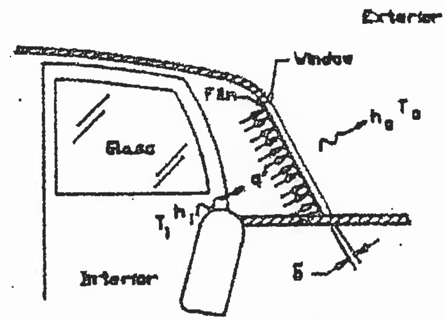
3. A two-stage double acting air compressor, operating at 150 revolutions per minute, takes in air at 96.5 kPa and 27°C. The diameter of the LP cylinder is 36 cm, the stroke of both the LP cylinder and the HP cylinder is 38 cm and the clearance of both cylinders is 4%. The LP cylinder discharges air at 386.0 kPa which passes through an intercooler and enters the HP cylinder at 27°C and 370 kPa after which it is discharged from the HP compressor at a pressure of 1482 kPa. The polytropic coefficient in both cylinders n = 1.3. Atmospheric pressure and temperature are 101.325 kPa and 20°C respectively. Disregarding the effect of the piston rods at the crank ends of the cylinders, determine (a) how much heat is rejected in the intercooler (b) the diameter of the HP cylinder and (c) the power required to drive each of the compressors.

4. Since low temperatures can be attained through adiabatic expansion of gas, refrigeration can be effected in this way. A system based upon this principle is suited for air craft applications because it is light and requires less space than a vapour compression system of equal capacity. The air conditioning unit of an aircraft receives air from the engine superchargers at 105 kPa and 35°C. The air is further compressed to pressure p by means of a compressor driven by a turbine. It is then cooled at constant pressure before expanding in the turbine to a pressure of 100 kPa and a temperature of 18°C. Assuming ideal conditions, determine pressure p if the turbine is to produce sufficient work to drive the compressor.



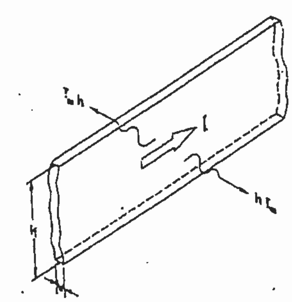
PART B - HEAT TRANSFER

5. The rear window of an automobile $\delta = 4$ mm thick with a thermal conductivity $k = 1.4$ W/m°C is defogged by passing an electric current through a thin transparent film type heating element bonded to its inner surface which generates a uniform heat flux q". (a) What power must be provided per unit area to achieve an inner surface temperature of $T_s = 15$°C when the temperature of the air in the automobile $T_i = 25$°C, the heat transfer coefficient at the inner surface $h_i = 10$ W/m²°C, the heat transfer coefficient at the outer surface $h_o = 65$ W/m²°C and the temperature of the air outside the automobile $T_o = -10$°C ? (b) Find the temperature of the inner surface of the window if the heat flux q" = 2500 W/m². (c) What would the temperature of the inner surface of the window be if the heat flux were zero ?

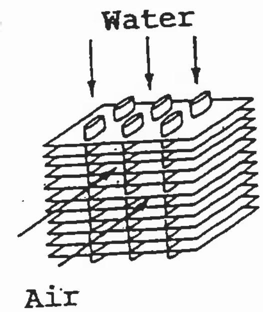


6. A steel tube 150 mm inside diameter with a 10 mm wall thickness conveying wet steam at 200°C is surrounded by air at 25°C. The loss of heat under these conditions is 2000 W/m. Determine the loss of heat when the tube is covered with a 20 mm thick layer of insulation given that the thermal conductivities of the insulation and the tube are respectively 0.35 W/m°C and 46.7 W/m°C respectively and the heat transfer coefficient between the metal and the air is 40% greater than the heat transfer coefficient between the insulation and the air.

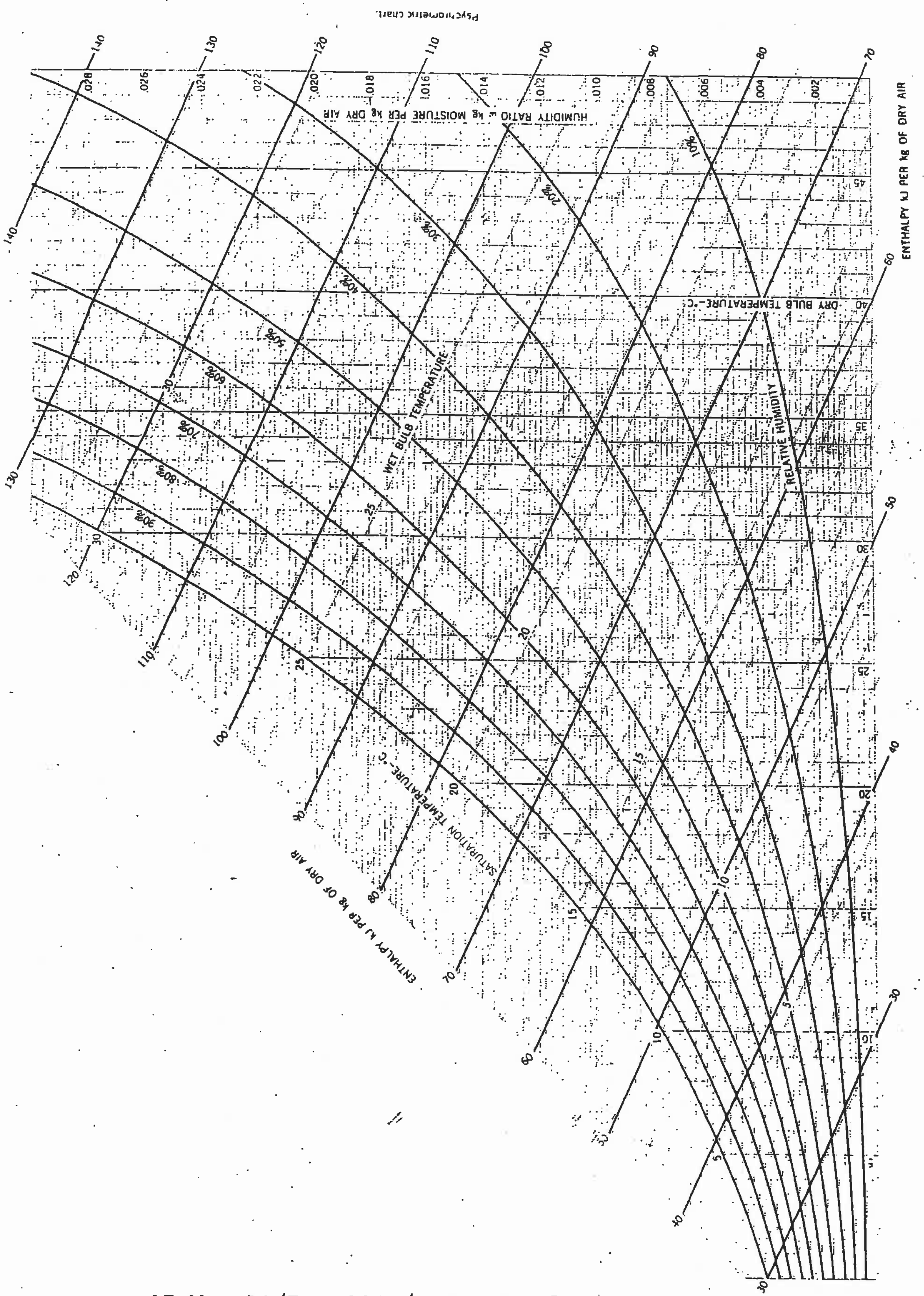
7. A busbar which takes the form of a strip with height H ten times as large as width W is to be made of copper having electrical resistivity $\rho = 2\times10^{-8}$ ohm m which is to be used in the determination of the electrical heat generation $q = I^2R$. I is the electric current flowing in the busbar and R is the electrical resistance of the busbar $R = \rho L/A_{cs}$ where L is the length of the busbar and $A_{cs} = WH$ is the cross sectional area of the busbar. It is intended that the busbar which will run horizontally with the heat transferring surfaces $A_s = HL$ oriented vertically is to be designed to operate at 87.8°C in quiescent air at 32.2°C. Assuming that radiation from all surfaces and convection from the top and bottom surfaces of the busbar may be neglected, determine the height of the busbar H if the current I = 10,000 amperes.

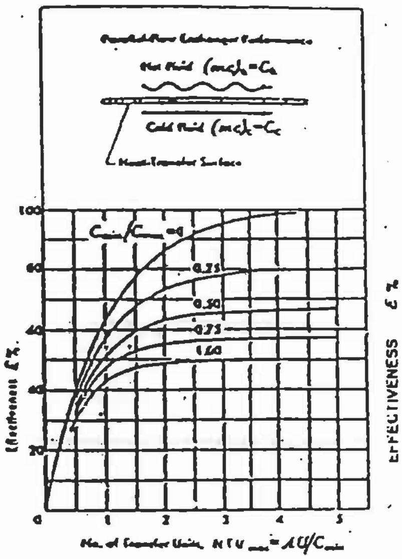


8. A home air conditioning system uses a crossflow finned tube heat exchanger like that depicted in the diagram to cool air flowing at 0.80 kg/s from 30°C to 7°C. The energy is transferred to water flowing at 0.76 kg/s which enters the heat exchanger at 3°C. Calculate the heat exchanger area required assuming an overall heat transfer coefficient of 55 W/m²°C. Assuming that the overall heat transfer coefficient is not affected, what percentage reduction in heat transfer rate will occur if the water flowrate is cut in half while the air flowrate is maintained constant ?

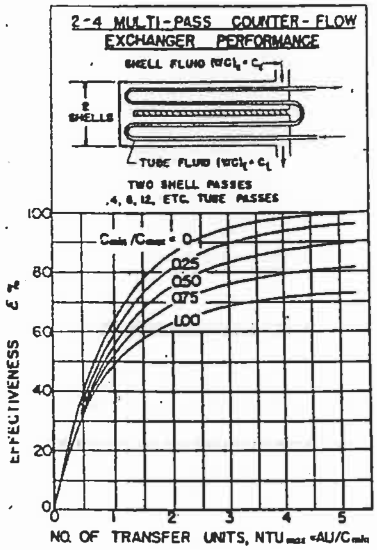


For Use in the Solution of Question 2

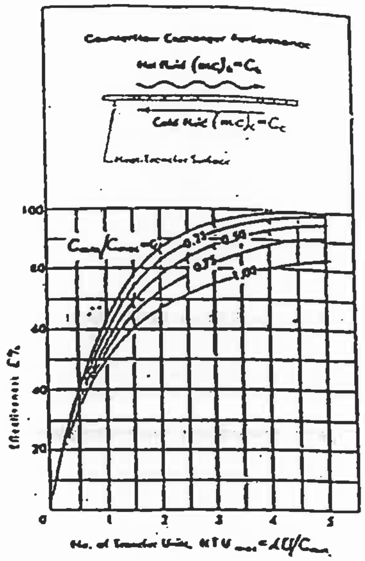




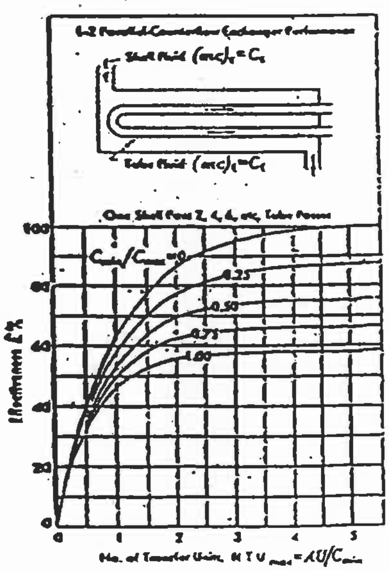
Heat-exchanger effectiveness for parallel flow. (By permission from W. M. Kays and A. L. London, *Compact Heat Exchangers*, National Press, 1955)



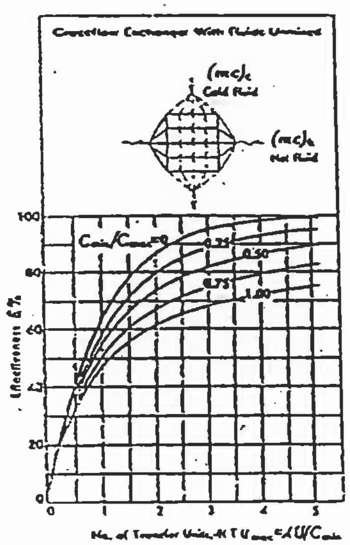
Heat-exchanger effectiveness for shell-and-tube heat exchanger with two well-baffled shell pass and two, or a multiple of two, tube passes. (By permission from W. M. Kays and A. L. London, *Compact Heat Exchangers*, National Press, 1955)



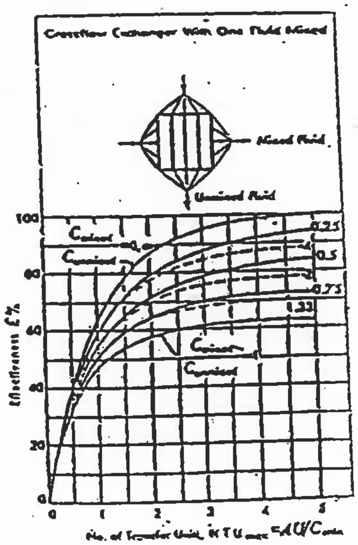
Heat-exchanger effectiveness for counterflow. (By permission from W. M. Kays and A. L. London, *Compact Heat Exchangers*, National Press, 1955)



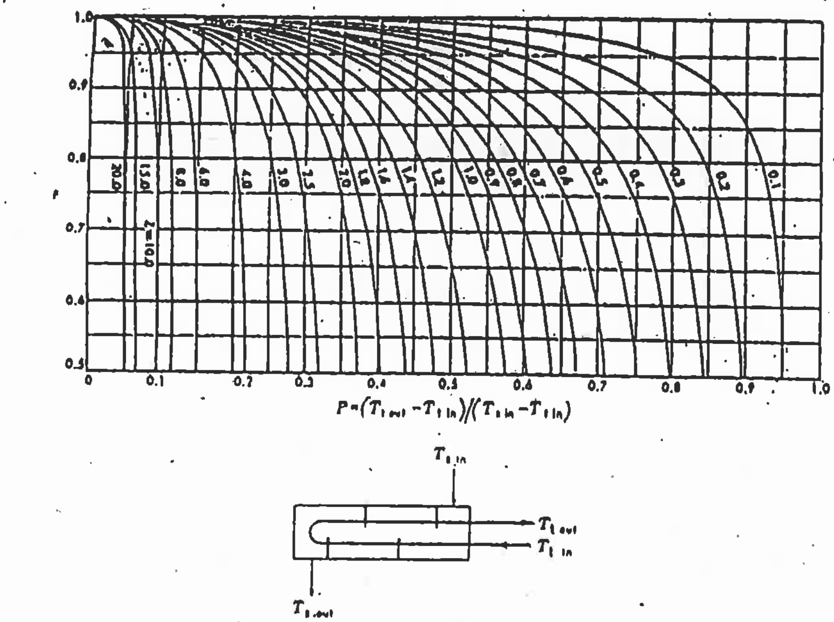
Heat-exchanger effectiveness for shell-and-tube heat exchanger with one well-baffled shell pass and two, or a multiple of two, tube passes. (By permission from W. M. Kays and A. L. London, *Compact Heat Exchangers*, National Press, 1955)



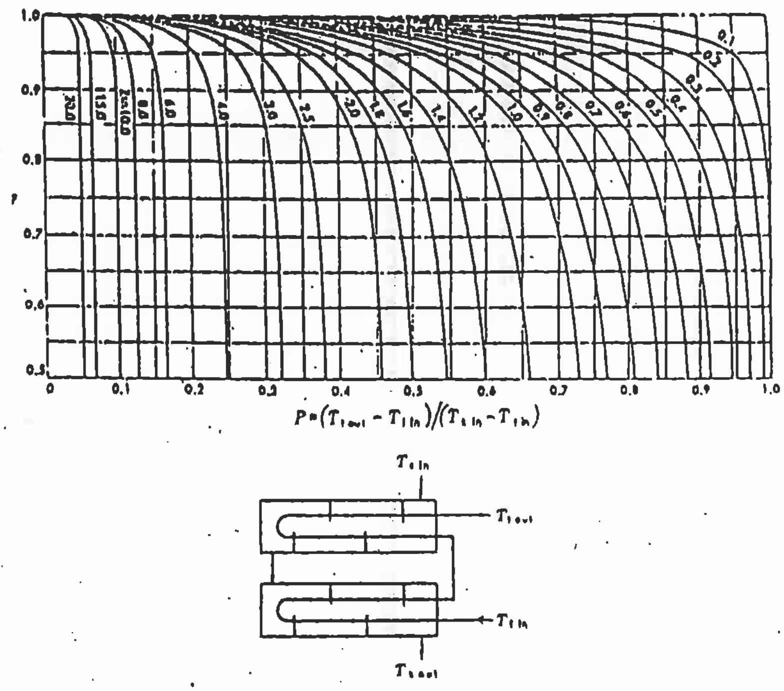
Heat-exchanger effectiveness for crossflow with both fluids unmixed. (By permission from W. M. Kays and A. L. London, *Compact Heat Exchangers*, National Press, 1955)



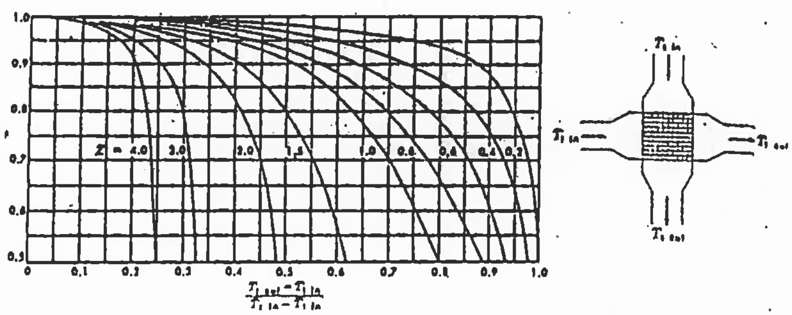
Heat-exchanger effectiveness for crossflow with one fluid mixed, the other unmixed. When $C_{mixed}/C_{unmixed} > 1$, NTU_{max} is based on $C_{unmixed}$ (By permission from W. M. Kays and A. L. London, *Compact Heat Exchangers*, National Press, 1955)



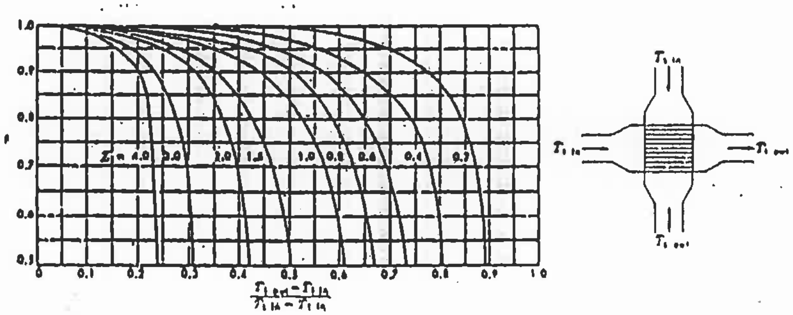
Correction factor to counterflow LMTD for heat exchanger with one shell pass and two, or a multiple of two, tube passes. (Courtesy of the Tubular Exchange Manufacturer's Association)



Correction factor to counterflow LMTD for heat exchanger with two shell passes and a multiple of two tube passes. (Courtesy of the Tubular Exchange Manufacturer's Association)



Correction factor to counterflow LMTD for crossflow heat exchanger, both fluids unmixed, one tube pass. (Extracted from "Mean Temperature Difference in Design," by R. A. Bowman, A. C. Mueller, and W. M. Nagel, published in *Trans. ASME*, Vol. 62, 1940, with permission of the publishers, The American Society of Mechanical Engineers)



Correction factor to counterflow LMTD for crossflow heat exchangers, fluid on shell side mixed, other fluid unmixed, one tube pass. (Extracted from "Mean Temperature Difference in Design," by R. A. Bowman, A. C. Mueller, and W. M. Nagel, published in *Trans. ASME*, Vol. 62, 1940, with permission of the publishers, The American Society of Mechanical Engineers)