Fundamentals of Heat Transfer

Muhammad Rashid Usman

Institute of Chemical Engineering and Technology

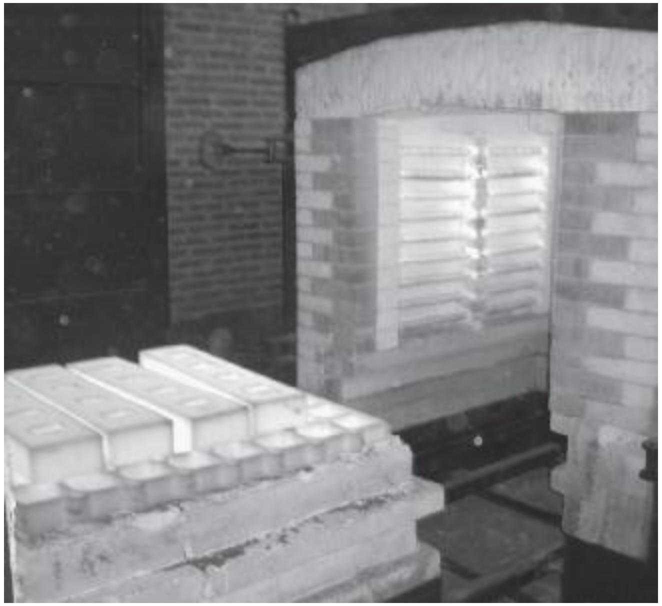
University of the Punjab, Lahore.

Figure taken from: http://heatexchanger-design.com/2011/10/06/heat-exchangers-6/ Dated: 17-Jan-2012

Course contents mid term

Introduction to transfer processes. Definition, applications, and various units of heat transfer. Modes of heat transfer: Conduction, convection, and radiation heat transfer. Fourier's law of heat conduction. Thermal conductivity of gasses, liquids, and solids. Units of thermal conductivity. Effect of temperature, pressure, and composition on thermal conductivity of materials. Estimation of thermal conductivity of gases, liquids, and solids. Introduction to steady-state heat transfer. Heat conduction through plane wall, hollow cylinder, and hollow sphere. Numerical problems related to heat conduction through plane wall, hollow cylinder, and hollow sphere. Thermal resistances in series: Composite plane wall, composite hollow cylinder, and composite hollow sphere. Numerical problems related to heat conduction through composite plane wall, composite hollow cylinder, and composite hollow sphere. Free and forced convection. Rate equation for convective heat transfer coefficient. Brief description of hydrodynamic boundary layer and heat transfer coefficient. Units of heat transfer coefficient. Individual and overall heat transfer coefficients: plane wall and hollow cylinder. Numerical problems regarding overall heat transfer coefficient. Determination of heat transfer coefficient. Description of various heat transfer correlations. Heat transfer in coiled and jacketed agitated vessels.

Typical kilns and furnaces [10]



Insulation types and applications [2]

Type		Temperature range, °C	Thermal conductivity, mW/m · °C	Density, kg/m^3	Application
1	Linde evacuated superinsulation	−240–1100	0.0015–0.72	Variable	Many
2	Urethane foam	−180–150	16–20	25–48	Hot and cold pipes
3	Urethane foam	−170–110	16–20	32	Tanks
4	Cellular glass blocks	−200–200	29–108	110–150	Tanks and pipes
5	Fiberglass blanket for wrapping	−80–290	22–78	10–50	Pipe and pipe fittings
6	Fiberglass blankets	−170–230	25–86	10–50	Tanks and equipment
7	Fiberglass preformed shapes	−50–230	32–55	10–50	Piping
8	Elastomeric sheets	−40–100	36–39	70–100	Tanks
9	Fiberglass mats	60–370	30–55	10–50	Pipe and pipe fittings
10	Elastomeric preformed shapes	−40–100	36–39	70–100	Pipe and fittings
11	Fiberglass with vapor barrier blanket	−5–70	29–45	10–32	Refrigeration lines
12	Fiberglass without vapor barrier jacket	to 250	29–45	24–48	Hot piping
13	Fiberglass boards	20–450	33–52	25–100	Boilers, tanks, heat exchangers
14	Cellular glass blocks and boards	20–500	29–108	110–150	Hot piping
15	Urethane foam blocks and boards	100–150	16–20	25–65	Piping
16	Mineral fiber preformed shapes	to 650	35–91	125–160	Hot piping
17	Mineral fiber blankets	to 750	37–81	125	Hot piping
18	Mineral wool blocks	450–1000	52–130	175–290	Hot piping
19	Calcium silicate blocks, boards	230–1000	32–85	100–160	Hot piping, boilers, chimney linings
20	Mineral fiber blocks	to 1100	52–130	210	Boilers and tanks

P.1 [3]

Consider a 3 m high, 5 m wide, and 0.3 m thick wall whose thermal conductivity is k =0.9 W/m·°C. On a certain day, the temperatures of the inner and the outer surfaces of the wall are measured to be 16°C and 2°C, respectively. Determine the rate of heat loss through the wall on that day.

P.2

At steady-state conditions, a slab with thickness of 30 mm conducts heat at the rate of 10 W. The width and height of the slab are 10 in and 12 in, respectively. If the temperatures at the cold and hot ends are maintained at 30°C and 50°C, calculate the thermal conductivity of the material in the units of W/m·K, cal/s·cm·°C, and Btu/h·ft·°F.

Insulation types and applications [2]

P.3 [6]

A layer of pulverized cork 6 in thick is used as a layer of thermal insulation in a flat wall. The temperature of the cold side of the cork is 40 °F and that of the warm side is 180 °F. The thermal conductivity of the cork at 32 °F is 0.021 Btu/ft·h·°F and that at 200 °F is 0.032 Btu/ft·h·°F. The area of the wall is 25 ft^2. What is the rate of heat flow through the wall in Btu per hour?

P.4 [7]

A furnace is constructed with 0.20 m of firebrick, 0.1 m of insulating brick, and 0.20 m of building brick. The inside temperature is 1200 K and outside temperature 330 K. If thermal conductivities are given as, for firebrick = 1.4 W/m·K, for insulating brick = 0.21 W/m·K, for common brick = 0.7 W/m·K. Find the heat loss per unit area and the temperature at the junction of firebrick and the insulating brick.

Insulation types and applications [2]

P. 5

An industrial furnace wall is composed of three plane walls, namely 0.10 m thick fireclay wall, 0.15 m wide insulation wall, and 0.20 m wide common brick wall. Thermal conductivities of fireclay brick, insulating brick, and common brick are 1.5 W/m·K, 0.20 W/m·K, and 1.0 W/m·K, respectively. The inside composite wall temperature is 1300 K and the outside composite wall temperature is 300 K. Calculate the heat loss per unit area and the temperatures at the junctions of the individual walls. Also calculate the thermal resistance of each wall.

P.6 [2]

A wall 2 cm thick is to be constructed from material that has an average thermal conductivity of 1.3 W/m·°C. The wall is to be insulated with material having an average thermal conductivity of 0.35 W/m·°C, so that the heat loss per square meter will not exceed 1830 W. Assuming that the inner and outer surface temperatures of the insulated wall are 1300 and 30 °C, calculate the thickness of insulation required.

Insulation types and applications [2]

P.7 [2]

An exterior wall of a house may be approximated by 4 in layer of common brick, with thermal conductivity 0.7 W/m·°C followed by 1.5 in layer of gypsum plastic with thermal conductivity of 0.48 W/m·°C. What thickness of rock wool insulation with thermal conductivity 0.065 W/m·°C should be added to reduce the heat loss or gain through the wall by 80%.

P.8 [2]

A thick-walled tube of stainless steel [18% Cr, 8% Ni] with 2 cm internal diameter and 4 cm outer diameter is covered with a 3 cm layer of an insulation with thermal conductivity of 0.2 W/m·°C. If the inside wall temperature of pipe is maintained at 600°C and outside of insulation at 100°C, calculate the heat loss per meter of length. The thermal conductivity of stainless steel tube is 19 W/m·°C.

Insulation types and applications [2]

P.9 [6]

A 3 in outer diameter steel pipe is covered with a 0.5 in layer of asbestos which is covered with 2.0 in layer of glass wool. Determine the steady-state heat transfer per linear foot and interface temperature between asbestos and glass wool if the outer surface temperature is 400 °F and glass wool outer temperature is 100 °F. Take thermal conductivities from a literature source.

P.10 [6]

A standard 1 in Schedule 40 steel pipe carries saturated steam at 250 °F. The pipe is lagged (insulated) with a 2 in layer of 85% magnesia pipe covering, and outside this magnesia there is a 0.5 in layer of cork. The inside temperature of the pipe wall is 249 °F, and the outside temperature of the cork is 90 °F. Thermal conductivities, in Btu/ft·h·°F, are: for steel, 26; for magnesia, 0.034; for cork, 0.03. Calculate (*a*) the heat loss from 100 ft of pipe in Btu per hour; (*b*) the temperatures at the boundaries between metal and magnesia and between magnesia and cork.

Insulation types and applications [2]

P. 11 [6]

A tube 60 mm OD is insulated with a 50 mm layer of silica foam, for which the thermal conductivity is 0.055 W/m·°C, followed by a 40 mm layer of cork with a thermal conductivity of 0.05 W/m·°C. If the temperature of the outer surface of the pipe is 150 °C and the temperature of the outer surface of the cork is 30 °C, calculate the heat loss in watts per meter of pipe.

P. 12 [2]

A hot steam pipe having an inside surface temperature of 250°C has an inside diameter of 8 cm and a wall thickness of 5.5 mm. It is covered with a 9 cm layer of insulation having k = 0.5 W/m·°C, followed by a 4 cm layer of insulation having k = 0.25 W/m·°C. The outside temperature of the insulation is 20 °C. Calculate the heat lost per meter of length. Assume k = 47 W/m·°C for the pipe.

P. 13 [6]

A flat furnace wall is constructed of a 4.5 in layer of silocel brick with a thermal conductivity of 0.08 Btu/ft·h·°F backed by a 9 in layer of common brick, of conductivity 0.8 Btu/ft·h·°F. The temperature of the inner face of the wall is 1400°F and that of the outer face is 170°F. (a) What is the heat loss through the wall? (b) What is the temperature of the interface between the refractory brick and the common brick? (c) Supposing that the contact between the two brick layers is poor and that a "contact resistance" of 0.50 ft·h·°F/Btu is present, what would be the heat loss?

References

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