

SAULT COLLEGE OF APPLIED ARTS AND TECHNOLOGY

SAULT STB. MARIB, ON

COURSE OUTLINE

COURSE TITLE: APPMFn THFPMnnvMAMir< _____;

CODE NO.: MCH 304 SEMESTER: SIXTH

PROGRAM: MECHANICAL TECHNOLOGY

AUTHOR: W. J. ADOLPH

DATE: JUNE > 1993 PREVIOUS OUTLINE DATED: JUNE, 1983

APPROVED: ofPSL^,*^- /7fî ^ O 7 " /£
CHAIRPERSON J DATE

- 2 -

CALENDAR DESCRIPTION

APPLIED THERMODYNAMICS

MCH 304

Course Name

Course Number

PHILOSOPHY/GOALS;

It is the intent of this course to provide the student of thermodynamics with meaningful examples of the application of thermodynamics principles *a* found in boiler plant air conditioning, heat transfer and gas mixing. This also provides another opportunity to improve the quality of the students production of well organized and professional looking solutions.

METHOD OF ASSESSMENT (GRADING METHOD):

There are four topics to be tested thus four tests worth approximately the same. Laboratory assignments will be marked and will contribute about 25 to the final grade.

Grades: A 80 - 100%
B 69 - 79%
C 55 - 69%

TEXTBOOK(S):

Applied Thermodynamics for Engineering Technologists
T. D. Eastop and A. McConkey, 3rd Edition, Longman.

STEAM PLANTTOPIC £ 1_

The student will be able to:

Ranking Cycle

1. Note that the Carnot cycle is the most efficient for the conversion of heat to work,
2. Explain why the Carnot cycle is not a practical cycle especially when using steam vapour as its working fluid.
3. Draw the Rankine cycle on a T-s diagram and a schematic of the equipment required in this cycle.
4. Explain each process of the Rankine cycle and list the equipment related to that process.
5. Write the equation for steady flow energy noting which terms can be considered zero.
6. List the steady flow energy equations that apply to the following equipment:
 - a) Turbine
 - b) Condenser
 - c) Pump
 - d) Boiler
7. Write the formula for Rankine Efficiencies in terms of enthalpies at various points in the cycle.
8. Write the equation $W_{\text{pump}} = H^{\wedge} - H_3 = v_{(D4_D3)}$
9. Write the equations for "isentropic efficiency" of:
 - a) expansion processes
 - b) compression processes in terms of enthalpies
10. Recall the equation for Work Ratio.
11. Define "specific steam Consumption" write its formula and prove the units of $\frac{\text{kg}}{\text{kwh}}$
12. Calculate the cycle efficiency, the work ratio and the S.S.C. for a steam power plant operating between the boiler pressure of 42 bar and a condenser pressure of 0.035 bar, for:
 - a) A Carnot cycle using wet steam
 - b) A Rankine cycle with dry saturated steam at entry to the turbine.
 - c) The Rankine cycle of (b) when the expansion process has an isentropic efficiency of 80%.

Draw the process on T-s diagrams.

Rankine With Superheat

13. Recall the meaning of "Superheat".
14. Make a drawing of the equipment necessary to provide the Rankine cycle performance of 12 above with that obtained when the steam is superheated. Neglect the feed pump work. Draw conclusions about the effect of superheating upon S.S.C. and efficiency.
15. Make a drawing of the equipment necessary to provide the Rankine cycle with "superheat". Draw the appropriate T-s diagram.

16. Make a sketch of the Rankine cycle with superheat, showing the isentropic expansion terminating very near the dome. Explain the advantage, of such an expansion.
17. Draw a conceptual entropy diagram for steam showing families of constant pressure line, constant dryness, constant temperature and the critical point.

Dryness Fraction

18. Recall the formulae and procedure for determining the dryness fraction of steam on a main by use of:
 - a) a throttling calorimeter
 - b) a combination separating and throttling calorimeter

Steam Condenser

19. State the function of a steam condenser.
20. List the two major types of steam condensers.
21. Describe and sketch the shell type and the tube type surface condenser.
22. Describe and sketch the evaporative condenser.
23. Describe the operating principle of an Air ejector.
24. Describe the operating principle of an "injector" used to feed water into the boiler.

Reheat Cycle

25. Explain why "reheating" of the steam is done.
26. Make an equation of the Rankine cycle with reheat on a T-s diagram.
27. Write an equation for efficiency of the Rankine cycle with reheat in terms of enthalpies.
28. Calculate the new cycle efficiency and S.S.C. if reheat is added to cycle of 15. The steam conditions at inlet to the turbine are 42 bar and 500°C and condenser pressure is 0.035 bar. Assume that the steam is just drysat on leaving the first turbine and is reheated to its initial temperature. Neglect the feed pump work. Draw conclusions the effect of reheat.

Regenerative Cycles

29. Draw the schematic of the equipment needed to run a regenerative cycle and draw the T-s diagram for a Rankine cycle modified for regeneration.
30. Calculate the cycle efficiency and the specific steam consumption of the cycle of (12), modified to include one feed heater. If the steam enters the turbine at 42 bar, drysat and condenser pressure is 0.03 bar.

31. Sketch the schematic and the T-s diagram of Rankine Cycle with two "closed heaters".
32. Describe how economizers and preheater coils increase plant efficiency.
33. Explain the meaning of the following terms:
 - a) Higher calorific value
 - b) Lower calorific value
 - c) Boiler capacity
 - d) Equivalent evaporation
 - e) Boiler efficiency
34. Explain "Binary vapour cycle".
35. Briefly describe the nature and application of the following types of boilers:
 - a) Radiant type
 - b) Super contical type
 - c) Steam generators
 - d) Electrode type
36. Explain why "heating and process" boilers have higher efficiency than "power" boilers.
37. Define with sketches:
 - a) Back pressure turbines
 - b) Pass-out back pressure turbines
 - c) Back pressure and exhaust turbine
 - d) Mixed pressure turbine

MIXTURES

TOPIC f 2

The student will be able to:

The Gibbs-Dalton Law:

1. State Daltons law relating partial pressure of gas constituents to pressure of the mixture.
2. Define the term "partial pressure".
3. List the formulae relating:
 - a) Total mass to constituent masses.
 - b) Total pressure to constituent pressures.
4. Define "volumetric" and "gravimetric" analysis.
5. State the analysis of "atmospheric air" by
 - a) volume
 - b) mass
6. Determine the partial pressure of each constituent and the total pressure in a vessel of 0.m3 containing 0.45 kg of carbon dioxide and 1 kg of air both at 15°C. Use atmospheric air.
7. State Gibbs-Dalton Law which relates to internal energy, enthalpy and entropy of gas mixture.
8. List the formulae arising out of the Gibbs-Dalton Law.

Volumetric Analysis of a Gas Mixture

10. Write the formula and the precise meaning of the equation which relates the volumes of individual constituents to the volume of a mixture of gases.
11. Write the formula which relates moles of constituent gases in a mixture to moles of mixture.
12. Write the equations relating:
 - a) moles to kilograms
 - b) P_o to R
 - c) The apparent Molecular Wt to specific Molecular Wt
 - d) The apparent gas constant to the specific gas constant.
13. Calculate the gas constant for air, and the apparent molecular weight if the gravimetric analysis of air is 23.14% oxygen, 75.53% nitrogen, 1.28% argon and 0.05% Carbon Dioxide.
14. Write the equations of ratios relating pressures moles, and volumes of mixtures and constituents.
15. Determine the volumetric analysis and the partial pressure of each constituent for a mixture having a gravimetric analysis of 23.14% oxygen, 75.53% nitrogen, 1.28% argon, and 0.05% carbon dioxide. Total pressure is 1 bar.
16. For the mixture, calculate:
 - a) The masses of CO_2 , O_2 and A_2 and total mass
 - b) The percentage of carbon by mass
 - c) The apparent molecular weight and the gas constant for the mixture
17. For a mixture of 1 mole CO_2 and 3.5 moles of air contained in a vessel at 1 bar and $15^\circ C$. Assume atmospheric air. Calculate the mass of H_2 required and the volume of the vessel needed based upon 1 kg of H_2 , such that the ratio of hydrogen to oxygen is 2 to 1 by volume. Pressure and temperatures are 1 bar and $15^\circ C$ respectively.
18. Calculate based upon a mole of mixture, the mass of mixture to be removed and the mass of Carbon Monoxide to be added so that the final mixture of 50% hydrogen and 50% CO will result from an initial mixture of 80% H_2 and 20% CO . Assume that pressure and temperature in the vessel remain constant always.

Specific Heats of a Gas Mixture

19. From the Gibbs-Dalton law relating internal energies of constituents and mixtures, develop the relationship for the specific heat of constituents and mixtures.
20. List the similar equation relating:
 - a) C_p
 - b) R

21. Calculate the work done and the heat flow per kg of gas_f when a gas in an engine cylinder, having a volumetric analysis of 12% CO₂, 11.5% O₂ and a 76.5% N₂ expands reversibly from 1000°C through a volume ratio 7 to 1 according to the polytropic law, $p v^{1.25} = C$. Use the following values of c_p :
- CO₂ - 1.235
O₂ - 1.088
N₂ - 1.172
22. Calculate the change of entropy per kg of mixture for #31. Draw the T-s diagram for the change.

Molar Heats of Constituents and Mixtures

23. Write the equations for molar heats of constituents and mixtures.
24. Write the equation relating molar heats to specific heats*
25. Calculate the molar heats and specific heats of mixtures of the in a "producer gas" which has the following analysis by volume. 29% H₂, 12% H₂, 3% CH₄, 4% CO₂, 52% N₂.

Adiabatic Mixing of Perfect Gases

26. Write the formulae relating the temperature of a mixture to the temperatures of the constituents for
a) non-flow processes
b) steady flow processes
27. Calculate the final temperature and pressure of the mixture and the change of entropy of the mixing system when a vessel of 1.5 M³ containing oxygen at 7 bar and 40 C is connected to another vessel of 3M³ containing carbon monoxide at 1 bar and 15 C. The connecting valve is opened allowing adiabatic mixing.

Gas and Vapour Mixtures

28. Recall that the Gibbs-Dalton law states that each constituent behaves as if alone occupied the whole vessel at the temperature of the vessel.
29. Explain what happens to liquid if various quantities of it are introduced into an evacuated vessel, until the vapour so formed finally assumes the pressure corresponding to its saturation pressure.
30. Calculate the mass of water to be injected into a vessel so that the vessel is just filled with saturation vapour the vessel of 0.3m³ contains air at 0.7 bar and 75°C. This temperature is maintained as water is injected into it,
31. Determine the final pressure of vessel of a 3m³ filled with air at 0.7 bar and 75°C after 0.7 kg of water is injected into it. The temperature is maintained at 75°C during injection.
32. Calculate the temperatures to which a gas mixture of CO₂ 8%, H₂O 1-02 5.5% and N₂ 71.5% must be cooled at constant pressure for condensation of the H₂O just to commence.

PSYCHOMETRY

TOPIC f 2

The student will be able to:

1. Define "psychometry",
2. Note that at low vapour pressures, (below one atmosphere) the vapour can be considered to act as a perfect gas, and the properties of the mixture obey the Gibbs-Dalton law.
3. List the following formulas:
 - a) the relationship between total pressure, partial pressure of dry air and partial pressure of super-heated vapour
 - b) the relationship defining specific humidity
 - c) the relationship defining relative humidity
 - d) the relationship defining perant saturations
4. Define "dew point" of a pschometric mixture and specific humidity.
5. Determine the dew point of air in a room at 17°C having a relative humidity of 60%. Barometric pressure is 1.01325 bar.
6. Air at 17°C and = 60% is passed at a rate of 0.5 m³/5 over a cooling coil which is at a temperature of 6°C. Calculate the amount of vapoi which will be condensed if the air leaving the coil is saturated. Barometric pressure is 1,01325 bar.

Measurement of Relative Humidity

7. Make a sketch of a psychometric chart labelling every family of line
8. Explain what happens to the liquid levels of the two thermometers of sling psychometer when a stream of dry air passes over the dry bulb wet wick.
9. Demonstrate the use of the sling psychometer and the psychometric ch how the relative humidity, percent saturated dew point temperature a specific humidity are determined.
10. Define "air conditioning"•
11. Demonstrate the process for air conditioning "summer" air on a T-s diagram and on a psychometric chart.
12. Draw a line diagram of a typical air conditioning plant showing circulating fan, eliminator, heater, washer, refrigerator, pilers, < preliminary heaters.
13. List the fan work equation in terms of mass flow of air and vapour . temperature.
14. Calculate the condition at which the air must leave the heater, jus before the fan work addition. Fan input is 1.125kw pressure is 1.0 bar, and air delivered after fan input is at a flow rate of 0.5 m³/ 17 C dry bulb relative humidity of 60%.
15. Continuing with the data of 14, determine the temperature required the cooler and the heat input to the heater.
16. Continuing, determine the condition after mixing (before cooling) volumes of recirculating air at 25°C and 50% R.H. and 1 volume of f air at 29°C and 40% R.H.
17. Repeat 14, 15, and 16 using a pschometric chart.

18. Explain the construction and operation of a cooling tower, and draw a schematic of one.
19. Calculate, the final water temperatures and the amount of cooling water make up required for a small cooling tower designed to cool 5.5 litres of water each second, the inlet temperature of which is 44 C. The motor driven fan induces $9\text{m}^3/5$ of air through the tower and the power absorbed is 4.75 kw. The air enters the tower at 18 C and 60% R.H. and leaves saturated at 26°C. Atmospheric pressure is 1.013 bar.

HEAT TRANSFER

TOPIC £ A

The student will be able to:

1. List and explain the three mechanisms by which heat is transferred.

Fourier's Law of Conduction

2. State Fouriers law if the rated flow of heat and list the appropriate formulae.
3. Calculate the rate of heat transfer per m^2 of surface area of wall, 2 mm thick of planebrick, the outer surface of which is 20 C and the inner surface at 40 C. The thermal conductivity of the brick is 0.52 w/mk.

Newton's Law of Cooling

4. State Newtons law of cooling and write the equation describing it.
5. Write the equation for $1/v$ where V is the overall heat transfer for co-efficient, using the heat transfer co-efficient, as it arises out Newton law, and K the thermal conductivity as it arises of Fouriers law.
6. Write the equation relating the per-unit heat transfer to the overall heat transfer co-efficient and T.
7. Calculate the rate of heat loss per M^2 of tank surface area for a mi steel tank of wall thickness 10 mm, and containing water at 90 C. 1 atmospheric temperature is 15°C W/mk and the heat transfer per co-efficients for the inside and outside surface of the tank.

The Composite Wall

8. Define the term "thermal resistance" in terms of the heat transfer co-efficient.

9. Determine the rate of which heat is transferred through a furnace wall consisting of 125 mm of refractory brick 12.5 m, of insulating firebrick separated by an air gap. The outside wall is covered with 12 mm of plaster. The inner surface of the wall is 1100 C and room temperature is 25°C. The heat transfer co-efficient from the outside wall surface to the air in the room is 17 W/m²k and resistance to heat flow of the air gap is 0.16 k/w. The thermal conductivity of the brick, insulating firebrick and plaster are 1.6, 0.3, and 0.14 w/mk respectively.

Heat Flow Through a Cylinder and a Sphere

10. Write the formula and explain all the terms in the formula relating heat loss to change in temperatures.
11. Calculate the rate at which heat is lost by steam per unit length of pipe for a steel pipe of 100 mm bore, 7 mm wall thickness carrying steam of 260 C and having insulation of 40 mm of a moulded high temperature diatomaceous earth covering, which is in turn covered by 6 mm of asbestos felt. Atmospheric temperature is 15 C* The heat transfer co-efficients for inside and outside surfaces are 550 and 15 W/m²k respectively and the thermal conductivity of steel, diatomaceous earth and asbestos felt are 50,000 and 0.07 w/mk respectively. Also calculate the temperature on the outside of the insulation.

The Space

12. Write the formula for heat transfer through a spherical tank and explain each term.
13. Calculate the heat loss from a small hemispherical oven having an inner radius of 0.6 m, and build of an inner layer of insulating firebrick 125 mm thick and an outer covering of 85% magnesia 40 mm thick. The inner surface of the oven is 800°C and the heat transfer co-efficient for the outside surface is 10W/m²k. The room temperature is 20.C. Thermal conductivities of firebrick and 85% magnesia are, 31 and 0.05 w/mk respectively.

Heat Exchanger

14. Define the terms "recuperator" and "regenerator".
15. Make sketches of parallel flow and counter flow recuperators and draw temperatures length diagrams.
- 16 Write the equations for counter flow heat transfer and for parallel flow, and list the meaning of the various variables in that equation

17. State the effect the equations above when one of the fluids is a wet vapour or a boiling liquid.
18. Calculate, the surface for both parallel flow and counter flow required when cooling water flow is 0.04 kg/s past exhaust gases flowing through a tubular heat exchanger at the rate of 0.3 kg/s are cooled from 400°C to 120°C by water initially at 10°C. The specific heat of the exhaust gases and water may be taken as 1.3 and 4.19 kJ/kgK respectively and the overall heat transfer coefficient from gases to water is 140W/m²K.