Unit 5005: Further Thermodynamics

Unit Code: M/651/0859

Level: 5

Credits: 15

Introduction

From the refrigerators that we use in our homes to the colossal power stations that generate the electricity we use and provide power to industry, the significance that thermodynamics plays in the 21st century cannot be underestimated.

This unit aims to build on the techniques explored in *Unit 4013: Fundamentals of Thermodynamics and Heat Transfer*, to develop further students' skills in applied thermodynamics by investigating the relationships between theory and practice.

Among the topics included in this unit are: heat pumps and refrigeration, performance of air compressors, steam power plants, and gas turbines.

On successful completion of this unit, students will be able to learn about the performance and operation of heat pumps and refrigeration systems, the applications and efficiency of industrial compressors, the use of charts and/or tables to determine steam plant parameters and characteristics, and the operation of gas turbines and assess their efficiency.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Evaluate the performance and operation of heat pumps and refrigeration systems

LO2 Review the applications and efficiency of industrial compressors

LO3 Determine steam plant parameters and characteristics using charts and/or tables

LO4 Examine the operation of gas turbines and assess their efficiency.

Essential Content

LO1 **Evaluate the performance and operation of heat pumps and refrigeration systems**

Heat pumps and refrigeration:

Reversed heat engines: reversed Carnot and Rankine cycles

Second law of thermodynamics

Refrigeration tables and charts (p-h diagrams)

Coefficient of performance of heat pumps and refrigerators

Vapor compression refrigeration cycle

Refrigerant fluids: properties and environmental effects

Economics of heat pumps.

LO2 **Review the applications and efficiency of industrial compressors**

Performance of air compressors:

Theoretical and realistic cycles

Isothermal and adiabatic work

Volumetric efficiency

Intercoolers, dryers, and air receivers

Hazards and faults: safety consideration and associated legislation.

LO3 **Determine steam plant parameters and characteristics using charts and/or tables**

Steam power plant:

Use of tables and charts to analyse steam cycles

Circuit diagrams showing boiler, super heater, turbine, condenser, and feed pump

Theoretical and actual operation: Carnot and Rankine cycle

Efficiencies and improvements: sustainability and environmental efficiency considerations in decision-making.

LO4 **Examine the operation of gas turbines and assess their efficiency**

Gas turbines:

Single and double-shaft gas turbine operation

Property diagrams: Brayton (Joule) cycle

Intercooling, reheating, and regeneration

Combined heat and power plants

Self-starting and burner ignition continuation

Fuels and Combustion,

Theoretical and actual combustion

Enthalpy-of-formation, enthalpy of combustion, and heating value

Safety first culture and application within the context: use of health and safety policies, procedures and regulations, compliance, risk assessment and mitigation.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Evaluate the performance and operation of heat pumps and refrigeration systems		
P1 Using didactic sketches, evaluate the operating principles of both heat pumps and refrigeration systems. **P2** Use refrigeration tables and pressure/enthalpy charts to determine COP, heating effect, and refrigeration effect of reversed heat engines.	**M1** Assess the limiting factors that impact the economics of heat pumps. **M2** Illustrate the contradiction between refrigeration cycles and the second law of thermodynamics.	**D1** Conduct a cost–benefit analysis of the installation of a ground source heat pump on a smallholding to make valid recommendations for improvements.
LO2 Review the applications and efficiency of industrial compressors		
P3 Review the different types of industrial compressors and identify justifiable applications for each. **P4** Discuss compressor faults and potential hazards. **P5** Determine the volumetric efficiency of a reciprocating compressor.	**M3** Evaluate isothermal efficiency by calculating the isothermal and polytropic work of a reciprocating compressor.	**D2** Critically evaluate the volumetric efficiency formula for a reciprocating compressor.
LO3 Determine steam plant parameters and characteristics using charts and/or tables		
P6 Determine the need for superheated steam in a power-generating plant. **P7** Apply the use of charts and/or tables to establish overall steam plant efficiencies in power systems.	**M4** Justify why the Rankine cycle is preferred over the Carnot cycle in steam production plants around the world.	**D3** Critically evaluate the pragmatic modifications made to the basic Rankine cycle to improve the overall efficiency of steam generation power plants.
LO4 Examine the operation of gas turbines and assess their efficiency		
P8 Investigate the principles of operation of a gas turbine plant. **P9** Examine the efficiency of a gas turbine system.	**M5** Compare the actual plant and theoretical efficiencies in a single-shaft gas turbine system, accounting for any discrepancies found.	**D4** Evaluate the enthalpy of combustion, using enthalpy of formation for the gas turbines.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Assael M.J., Maitland G.C., Maskow T., Stockar U.V., Wakeham W.A. and Will S. (2022) *Commonly Asked Questions in Thermodynamics.* 2nd Ed. CRC Press.

Bejan A. (2016) *Advanced Engineering Thermodynamics.* John Wiley & Sons, Inc.

Borgnakke C. and Sonntag R. (2022) *Fundamental of Thermodynamics.* 10th Ed. Wiley.

Baskharone E. A. (2012) *Thermal Science: Essentials of Thermodynamics, Fluid Mechanics, and Heat Transfer.* McGraw Hill.

Cengel Y.A., Boles M.A. and Kanoglu M. (2019) *Thermodynamics: An Engineering Approach Si*. 9th Ed. McGraw Hill.

Dixon, S. L. and Hall C. (2013) *Fluid mechanics and thermodynamics of turbomachinery.* Butterworth-Heinemann.

Granet I., Alvarado J. and Bluestein M. (2021) *Thermodynamics and Heat Power.* 9th Ed. CRC Press.

Kleinstreuer C. (2021) *Essentials of Engineering Thermodynamics.* 1st Ed. McGraw-Hill.

Lloyd W. (Editor) (2023) *Handbook of Heat Transfer and Fluid Flow (Hardback).* Willford Press.

Murphy K. (Editor) (2023) *Engineering Thermodynamics: Simulation with Entropy (Hardback).* Clanrye International.

Potter M.C. and Somerton C.W. (2019) *Schaums Outline of Thermodynamics for Engineers.* 4th Ed. McGraw-Hill.

Rayner J. (2008) *Basic Engineering Thermodynamics*. 5th Ed. Pearson.

Trachenko K. (Author) (2023) *Theory of Liquids: From Excitations to Thermodynamics* (Hardback). Cambridge University Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Applied Thermal Engineering

International Communications in Heat and Mass Transfer

International Journal of Heat and Mass Transfer

International Journal of Turbomachinery, Propulsion and Power

International Journal of Thermal Sciences

Thermodynamics: A Section of Entropy

Journal of Turbomachinery

Links

This unit links to the following related units:

Unit 4013: Fundamentals of Thermodynamics and Heat Engines

Unit 5023: Thermofluids.