Course guide
820734 - EQT - Thermal Equipment

Last modified: 16/04/2024

Unit in charge: Barcelona School of Industrial Engineering
Teaching unit: 724 - MMT - Department of Heat Engines.

Degree: MASTER'S DEGREE IN ENERGY ENGINEERING (Syllabus 2013). (Compulsory subject).
MASTER'S DEGREE IN ENERGY ENGINEERING (Syllabus 2022). (Optional subject).

Academic year: 2024 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: Perez Segarra, Carlos David

Others: Carles Oliet Casasayas

PRIOR SKILLS

- Fundamentals of Thermodynamics, Fluid Mechanics, and Heat Transfer.
- It is not compulsory but advisable to have some basic knowledge of computer language (e.g. C++, C, Fortran, etc.)

REQUIREMENTS

Minimum of 10 ECTS completed in Thermal Engineering, including:
- Fundamentals of thermodynamics.
- Fundamentals of fluid mechanics.
- Fundamentals of heat transfer.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.
CEMT-7. Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.

Transversal:
CT3. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

TEACHING METHODOLOGY

The course teaching methodologies are as follow:
- Lectures and conferences by guest speakers.
- Participatory sessions: collective resolution of exercises, debates and group dynamics with the lecturer and other students in the lecture room; presentation of an activity individually or in small groups.
- Supervised theoretical/practical work: activities carried out individually or in small groups, under the supervision of the professor/lecturers.
- Homework assignment: design, planning and implementation of a project or homework assignment, to be carried out individually or by a group of students, and writing a report that should include the approach, results and conclusions.

The course face-to-face training activities are as follow:
- Lectures and conferences: learning based on understanding and synthesizing the know-how presented by the lecturers or by invited speakers.
- Participatory sessions: learning based on participating in the collective resolution of exercises, as well as in discussions and group dynamics, with the lecturer and other students in the lecture room.
- Presentations: learning based on presenting in the lecture room an activity individually or in small groups.
- Theoretical/practical supervised work: learning based on performing an activity in the lecture room, or a theoretical or practical exercises, individually or in small groups, with the support form the lecturers.

Study activities
- Homework assignments: learning based on applying and developing know-how.
- Self-study: learning based on studying or developing the contents of the learning material, individually or in groups, understanding, assimilating, analysing and synthesizing know-how.

LEARNING OBJECTIVES OF THE SUBJECT

Basic objectives of the course:
- description of selected thermal equipment: heat exchangers, heating, refrigeration and air conditioning systems, fired heaters
- introduction to basic simulation methodologies (analytical and computational tools, energy efficiency, optimization issues)
- consolidate and enhance the student's basic knowledge on thermodynamics, fluid mechanics and heat and mass transfer (thermal engineering fundamental issues)

Keywords: thermal systems and equipment, energy efficiency, ambient impact, design methods, optimization, heat exchangers, HVAC&R, natural fluids, sensitivity studies, thermodynamics, fluid dynamics, heat and mass transfer, combustion, furnaces, boilers.

At the end of the course the student:
- Is capable of describing the role of basic thermal equipment in the production and service sectors, as well as their importance in the energy chain: processing, transport, distribution and efficient use of energy.
- Is capable of selecting the most suitable thermal equipment from the energy point of view for each application (industry or services), and to analyze the performance of existing equipment.
- Is capable of proposing a project, at basic engineering scale or at functional scale, related to the design, sizing and/or the use of thermal equipment in various industrial and services sectors.
- Is capable of proposing improvements for thermal systems by developing new ideas.

STUDY LOAD

Type	Hours	Percentage
Hours large group	30,0	24.00
Guided activities	15,0	12.00
Self study	80,0	64.00

Total learning time: 125 h

CONTENTS

1-Introduction

Description:
Presentation of the course structure. Brief introduction to basic thermal equipment and their applications in thermal systems: heat exchangers, heating, refrigeration and air conditioning, heat generation by combustion, power plants, etc. Energy efficiency issues.

The subject is structured in three main blocks: heat exchangers, vapour compression refrigeration systems and combustors. Usually, the course starts with the heat exchangers block or, alternatively, with the combustors block. Refrigeration cycles are always given after heat exchangers because the presented methodology is needed in the analysis of two of their main components (evaporator and condenser). In any case, before starting any of the two mentioned blocks, heat exchangers or combustors, a brief review of fundamental concepts of thermodynamics, fluid mechanics and heat and mass transfer needed in this subject is carried out.

Specific objectives:
- Review of different thermal equipment: description, technical issues, applications in different thermal systems.
- Review of basic concepts of thermodynamics, fluid mechanics and heat and mass transfer (conduction, convection and radiation). Humid air.

Related activities:
- Proposal of different exercises of application.

Related competencies :
CEMT-7. Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.
CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.
CT3. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

Full-or-part-time: 18h
Theory classes: 6h
Self study : 12h

3. Heating, refrigeration and air conditioning

Description:
Introduction to the field of heating, refrigeration and air conditioning. Identification of the main thermal equipment and operating conditions. Design/selection of system components of vapour-compression refrigeration systems. Analysis of design and prediction of the whole cycle. Examples of application.

The student should acquire the knowledge and skills necessary for the description, selection and dimensioning of heating, refrigeration and air conditioning systems, as well as for the calculation of the performance of existing equipment and facilities.

Specific objectives:
- Description of vapour-compression refrigeration systems, for cooling or heating, and their components (evaporator, compressor, condenser, expansion device, intercoolers, etc.).
- Thermodynamic analysis of different refrigeration systems (single-stage and two-stage refrigeration systems, ejector refrigeration, systems with intermediate heat exchanger, flooded evaporator, etc.). Diagrams p-h and T-s. Examples of application.
- Condensers and evaporators. Classification, description and operating conditions. Extension of the methodology of design of heat exchangers to two-phase flows. Examples of applications.
- Compressors. Classification, description and operating conditions. Detailed analysis of reciprocating compressors. Calculation methodology. Examples of applications.
- Expansion devices. Classification, description and operating conditions. Detailed analysis of capillary tubes and thermostatic valves. Examples of applications.
- Prediction analysis of the whole refrigeration system and components.

Related activities:
- Proposal of exercises related to vapour compression refrigeration systems and their components
- Guided activity in the lab concerning transcritical CO_2 vapour-compression refrigerating cycles.

Related competencies :
CEMT-7. Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.
CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.
CT3. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

Full-or-part-time: 40h
Theory classes: 11h
Guided activities: 5h
Self study : 24h

2. Heat Exchangers

Description:
Introduction to heat exchangers. Detailed description and classification. Basic methodology of analysis considering prediction and design cases: F-factor, phi-NTU2 and e-NTU methods. Examples of application.

The student should acquire the knowledge and skills necessary for the description, selection and dimensioning of heat exchangers, as well as for the calculation of the performance of existing equipment and facilities.

Specific objectives:
- Classification of heat exchangers according to the type of fluids, interaction between currents, flow arrangements, and technological applications. Detailed description and mode of operation. Working parameters.
- General issues related to heat exchanger design: hermo-hydraulic and mechanical requirements, production process considerations, maintenance and cost reduction.
- Thermal and hydraulic analysis. Mathematical formulation considering single-phase flows. Methodology for design and prediction cases based on F-factor, phi-NTU2 and e-NTU methods. Extended surfaces (fins).
- Examples of application.

Related activities:
- Specific homework concerning the application of heat exchanger design methodologies.

Related competencies :
CEMT-7. Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.
CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.
CT3. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

Full-or-part-time: 36h 30m
Theory classes: 11h
Guided activities: 1h 30m
Self study : 24h

4. Fundamentals of combustion. Application to furnaces and boilers.

Description:
Introduction to boilers and furnaces: description and operating conditions. Combustion fundamentals and thermodynamic analysis. Heat transfer in a well-stirred furnace.

The student should acquire the knowledge and skills necessary for the description, selection and a preliminar dimensioning of fired heaters, as well as for the calculation of the performance of existing equipment and facilities.

Specific objectives:
- Introduction to boilers and furnaces: description and operating conditions.
- Combustion fundamentals. Chemical reactions and combustion. Mixture of perfect gases. Fuels. Complete, stoichiometric, lean and rich combustion. Elementary vs. overall reactions. Formation enthalpy. Heat of combustion, HHV and LHV. Temperature of the combustion products. Exercises of application.
- Zero-dimensional modelling of well-stirred furnaces. Overall energy balance and heat transfer to the load. Heat losses through the refractory walls. Temperature of the combustion gases. Exercises of application.

Related activities:
- Exercises of application.

Related competencies :
CEMT-7. Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.
CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.
CT3. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

Full-or-part-time: 30h 30m
Theory classes: 9h
Guided activities: 1h 30m
Self study : 20h

ACTIVITIES

1. Lectures of theory

Description:
Lectures of theory. Introduction (4 h); Heat exchangers (7 h); Heating, refrigeration and air conditioning (7 h); Combustion and fired heaters (6 h)

Full-or-part-time: 24h
Theory classes: 24h

1. Lectures of theory

Description:
Lectures of theory. Introduction (4 h); Heat exchangers (7 h); Heating, refrigeration and air conditioning (7 h); Combustion and fired heaters (6 h)

2. Lectures of applied exercises and problems

Description:
Lecture of applied exercises and problems: Introduction (2 h); Heat exchangers (4 h); Heating, refrigeration and air conditioning (4 h); Combustion and fired heaters (3 h).

Full-or-part-time: 13h
Theory classes: 13h

3. Guided activities

Description:
Guided activities: Heat exchangers (1.5 h); Heating, refrigeration and air conditioning (5 h); Combustion and fired heaters (1.5 h). Some of these activities involve guided work in the lab.

Full-or-part-time: 8h
Guided activities: 8h

4. Self study

Description:
Self study: Introduction (12 h); Heat exchangers (24 h); Heating, refrigeration and air conditioning (24 h); Combustion and fired heaters (20 h)

Full-or-part-time: 80h
Self study: 80h

GRADING SYSTEM

The evaluation is based on two exams, midterm and final exam, together with the presentation and defense of different assignments.

The midterm exam and the final exam account for a 30% and 45% of the final course mark, respectively.

Assignments (including a guided lab work) account for a 25% of the final course mark.

Students with a final course mark lower than 5 have the possibility of doing a retake exam. A positive evaluation of the retake exam is needed to pass the subject. The final course mark in such a case is 5.

EXAMINATION RULES.

The specific rules concerning individual and/or group work will be published in the teaching intranet (Atenea).

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

BIBLIOGRAPHY

Basic:

- Bergman, T.L.. Fundamentals of Heat and Mass Transfer. 8th ed. New York: Wiley, 2020. ISBN 9781119722489.
- Kakaç, S. [et al.] (eds.). Heat transfer enhancement of heat exchangers. Dordrecht: Kluwer Academic, 1999. ISBN 0792356373.
- Hundy, G.F. ; A.R. Trott ; T.C. Welch. Refrigeration, air conditioning and heat pumps [on line]. 5th ed. Amsterdam: Butterworth Heinemann, 2016 [Consultation: 20/04/2023]. Available on: https://www-sciencedirect-com.recursos.biblioteca.upc.edu/book/9780081006474/refrigeration-air-conditioning-and-heat-pumps. ISBN 0081006667.
- Rhine, J.M. ; R.J.Tucker. Modelling of gas-fired furnaces and boilers and other industrial heating processes. London: McGraw-Hill Book Company, 1991. ISBN 0-07-707305-3.

Complementary:

- Shah, R. K. ; Sekulic, Dusan P. Fundamentals of heat exchanger design. New York, [etc.]: John Wiley & Sons, 2003. ISBN 0471321710.
- Kakaç, K.; Liu, H.; Pramuanjaroenkij, A. Heat exchangers : selection, rating, and thermal design. 4th ed. Boca Raton, FL: CRC Press, 2020. ISBN 9781138601864.
- V. Ganapathy. Applied heat transfer. Tulsa, Okla.: PennWell Books, cop. 1982. ISBN 9780878141821.
- S. Kakaç. Boilers, evaporators, and condensers. New York: Wiley, cop. 1991. ISBN 9780471621706.
- ASHRAE. ASHRAE handbooks: 1. Fundamentals; 2. Refrigeration; 3. HVAC Systems and Equipment; 4. HVAC Applications. I-P and SI ed. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2008-. ISBN 9781936504084.
- Pizzetti, Carlo. Acondicionamiento del aire y refrigeración : [teoría y cálculo de las instalaciones]. 2ª ed, traducida de la 3ª ed. italiana. Madrid: Bellisco, 1991. ISBN 9788485198498.
- R. Viskanta. Radiative transfer of combustion systems : fundamentals and applications. U.S.: Begell House Publichers Inc., 2005. ISBN 1567002110.
- W.M.Rohsenow, J.P.Hartnett, Y.I.Cho. Handbook of heat transfer. 3rd ed. New York [etc.]: McGraw-Hill, cop. 1998. ISBN 9780070535558.