



Course guide

820760 - ETGCFM - Thermal Equipments for Heat and Cold Generation

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). (Optional subject).
ERASMUS MUNDUS MASTER'S DEGREE IN DECENTRALISED SMART ENERGY SYSTEMS (DENSYS) (Syllabus 2020). (Optional subject).
MASTER'S DEGREE IN THERMAL ENGINEERING (Syllabus 2021). (Compulsory subject).
MASTER'S DEGREE IN ENERGY ENGINEERING (Syllabus 2022). (Optional subject).

Academic year: 2024 **ECTS Credits:** 5.0 **Languages:** Catalan, Spanish, English

LECTURER

Coordinating lecturer: Carles Oliet

Others: Jesús Castro
Joaquim Rigola
Carlos David Pérez-Segarra

PRIOR SKILLS

Fundamentals of thermodynamics, fluid mechanics and heat transfer necessary to understand the operation of thermal equipment generating heat and cold.

REQUIREMENTS

Knowledge equivalent to having completed the course of levelling the Master's

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:

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.

Transversal:

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

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

Teaching methodology:

The course teaching methodologies are as follows:

- Lectures and conferences: presentation of knowledge by lecturers or guest speakers.
- Participatory sessions: collective resolution of exercises, debates and group dynamics, with the lecturer and other students in the classroom; classroom presentation of an activity individually or in small groups.
- Theoretical/practical supervised work (TD): classroom activity carried out individually or in small groups, with the advice and supervision of the teacher.
- Homework assignment of reduced extension: carry out homework of reduced extension, individually or in groups.
- Homework assignment of broad extension: design, planning and implementation of a project or homework of broad extension by a group of students, and writing a report that should include the approach, results and conclusions.
- Evaluation activities (EV).

Training activities:

The course training activities are as follows:

- Face to face activities
 - o Lectures and conferences: learning based on understanding and synthesizing the knowledge presented by the teacher or by invited speakers.
 - o 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 classroom.
 - o Presentations (PS): learning based on presenting in the classroom an activity individually or in small groups.
 - o Theoretical/practical supervised work (TD): learning based on performing an activity in the classroom, or a theoretical or practical exercise, individually or in small groups, with the advice of the teacher.
- Study activities
 - o Homework assignment of reduced extension (PR): learning based on applying knowledge and presenting results.
 - o Homework assignment of broad extension (PA): learning based on applying and extending knowledge.
 - o Self-study (EA): learning based on studying or expanding the contents of the learning material, individually or in groups, understanding, assimilating, analysing and synthesizing knowledge.

LEARNING OBJECTIVES OF THE SUBJECT

Learn the basics of thermodynamics and heat and mass transfer taking place in thermal systems and equipment generating heat and cold.

Knowing the different techniques for generating heat and cold.

Knowing the different methodologies that allow the calculation and design of thermal systems. Use of different calculation software, commercial and developed by CTTC-UPC (Heat Transfer Technology Centre, Polytechnic University of Catalonia).

Performing various experimental and numerical laboratory practice for testing thermal systems at CTTC-UPC to enable the student to become aware of specific applications, the possibilities of numerical methods and testing techniques, measurement and error estimation in this field of knowledge.

Learning Outcomes:

At the end of the course, the student:

Review basics of thermodynamics and heat transfer phenomena and mass (second law of thermodynamics, conservation equations, etc.), in the context of technological field of thermal systems and equipment generating heat and cold.

Description of the various technical options for refrigeration systems/heating. Technological peculiarities depending on application.

Application of advanced methods of numerical simulation analysis of items of equipment with one-dimensional fluids in which there is phase change. The treatment is performed for both steady and transient situations.

Introducing the most advanced calculation methods of items of equipment generating heat and cold on the analysis of fluids is multidimensional. Methods exposed macro control volumes (porosity type methods), methods based on solving the conservation equations assuming boundary layer as ultimately more advanced methods based on solving multidimensional detailed equations Navier- Stokes.

Comprehensive analysis systems (cooling cycles) calculates design and calculation of prediction. Global resolution techniques.

Conducting lab allowing the student aware of specific applications, the possibilities of the developed numerical methods and techniques of experimental measurement and estimation of experimental errors.



STUDY LOAD

Type	Hours	Percentage
Self study	85,0	65.38
Hours large group	30,0	23.08
Hours small group	15,0	11.54

Total learning time: 130 h

CONTENTS

Content 1. Introduction to cooling/heating systems

Description:

Basic concepts about typology and description of common cooling systems: vapour compression, absorption cycle of air, thermoelectric effect, etc.

Specific objectives:

Know the operation of heating and cooling system basics.

Be able to understand the scientific and technological interest of these thermal systems.

Related activities:

Theory class

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.

Full-or-part-time: 14h

Theory classes: 4h

Self study : 10h

Content 2. Heating and cooling systems by vapour compression

Description:

Review basic aspects of thermodynamics and heat transfer: equations of transport in integral form (conservation of mass, conservation of momentum, energy conservation, second law of thermodynamics).

Refrigerant fluids. General characteristics and classification. Non-contaminated refrigerants. Calculation of thermodynamic and transport properties in cases of pure fluids and mixtures.

Analysis component in the refrigeration circuit component:

Compressors: definition and types of income, comprehensive analysis (simplified) of calculation and advanced simulation of compressors.

Analysis of two-phase flows: phenomenology of condensation and evaporation, heat transfer evaluation, the volume fraction of steam and pressure loss. Multi-flow analysis. Advanced analysis of two-phase flows.

Condensers and evaporators. Characteristics depend on the type of fluid and specific aspects of the secondary cooling circuit (return of oil,...). Calculation of heat exchangers using analytical methods (F method factor, NTU,...). Advanced calculation of heat exchangers in two-phase flows. Condensation and ice formation on heat transfer surfaces.

Expansion devices: types, technological details, device selection for expansion. Calculation results for capillary tubes.

Auxiliary elements: pipe union, auxiliary heat exchangers, storage tanks, etc.

Comprehensive analysis of the cycle: design calculation and calculation of prediction. Global resolution techniques. Advanced transient analysis.

Specific objectives:

An overview of the basics of compression cooling systems.

Delve into the various components of a thermal system.

Be able to evaluate a complete cycle in the case of prediction and design.

Related activities:

Theory class

Practical class

Guided activity

Reduced scope work

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.

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

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

Theory classes: 8h

Guided activities: 4h

Self study : 24h



Content 3. Cooling/heating by absorption

Description:

Introduction: historical review, physical principle, thermodynamic analysis of absorption cycles: definition of income, analysis of absorption cycles.

Working fluids: absorbent systems with volatile (H₂O-NH₃) and non-volatile (LiBr-H₂O). Technological implications: simple effect, double effect, multiple effect (LiBr-H₂O), dual absorption cycle, GAX cycles (H₂O-NH₃). Other refrigerant-absorbent couples. Cooling absorption machines: cooling towers and air cooling.

Component to component analysis of the absorption circuit:

Absorbers: types according to refrigerant-absorbent and cooling (water-air).

Generators: types according to refrigerant-absorbent and energy source.

Analysis of the flow in descending film of liquid: phenomenology of the processes of absorption and desorption. Levels of simulation, governing equations and assumptions. Solvers. Effect of surfactants. Use of advanced surfaces of heat and mass transfer.

Condensers and evaporators: description of the type of exchanger as refrigerant-absorbent and method of cooling, technological details.

Elements of internal exchange to improve performance: exchanger solution, generator-absorber exchange (GAX), pre-cooler: types and technological details.

Auxiliary systems: vacuum equipment, purge systems, surfactant recovery, water recovery, decrystallisation systems.

Full system scan and absorption cycle: design and prediction. Use of zero-dimensional models and global balances. Study of the influence of external conditions on the system.

Specific objectives:

An overview of the basic aspects of cooling systems for absorption.

Delve into the different components of a thermal absorption system.

Be able to evaluate a complete cycle in the case of prediction and design.

Related activities:

Theory class

Practical class

Guided activity

Reduced scope work

Related competencies :

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.

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

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: 25h

Theory classes: 6h

Guided activities: 2h

Self study : 17h

Content 4. Load balancing cooling/heating

Description:

Cooling thermal loads: loads of product, loads of transmission, loads for internal sources, loads for infiltration, etc. Examples of application.

Packaging industry

Processes in industrial plants

Power generation plants

Cold chain

Processes for industrial ice

Cryogenic processes

Specific objectives:

An overview of the basics of balance loads.

Delve into the different concepts of loads.

Be able to assess examples of application.

Related activities:

Theory class

Practical class

Guided activity

Related competencies :

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.

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

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: 27h

Theory classes: 6h

Guided activities: 4h

Self study : 17h

Content 5. Combustion heat generators: boilers

Description:

Introduction: historical review, physical principle, thermodynamic analysis of the combustion heat generator: burners, boilers, hot air generators.

Fuels and combustion. Flames and burners.

Combustion processes. Stoichiometric reaction. Excess air. Adiabatic flame temperature. Heat losses. Post-combustion.

Boilers and hot air generators. Thermal performance.

Heat emitters.

Solar collectors.

Cogeneration and trigeneration cycles on power with steam turbines, gas turbines or alternative combustion engines.

Specific objectives:

An overview of the basics of heat generating equipment in general.

An overview of the basic aspects of the combustion process in particular.

Delve into the different concepts of cogeneration and heat emission.

Be able to evaluate examples of application.

Related activities:

Theory class

Practical class

Guided activity

Reduced scope work

Related competencies :

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.

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

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: 23h

Theory classes: 6h

Self study : 17h



ACTIVITIES

Theory classes

Description:

Methodology in large group. The content of the course follows a model of class exhibition and participation. The material has been organised in different groups of content according to the areas of knowledge of the course.

Specific objectives:

At the end of this activity, students should be able to master the knowledge, consolidate it and apply it correctly to various technical problems. Moreover, being a techno-scientific subject, the lectures should serve as a basis for the development of other more technical subjects related to the field of heat, such as Refrigeration, Thermal Motors or Solar Energy.

Material:

Recommended bibliography. Notes from professor (copies and/or ATENEA)

Delivery:

This activity is evaluated in conjunction with activity 2 (problems) through coursework and written test.

Related competencies :

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.

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: 20h

Self study: 20h



Practical classes

Description:

Methodology in large group and medium group, as long as the availability of the professor permits it. On each topic there will be some problems in the classroom so that students acquire the necessary guidelines to carry out this resolution: simplifying assumptions, approach, numerical resolution, discussion of results.

Specific objectives:

At the end of this activity, students should be able to apply theoretical knowledge to solve different types of problems. Given the methodology, students should be able to:

- 1.- Understand the statement and analyse the problem.
- 2.- Propose and develop a scheme of the same resolution.
- 3.- Solve the problem using proposed equations with a suitable algorithm resolution.
- 4.- Critically interpret the results.

Material:

Recommended bibliography. Notes from professor (copies and/or ATENEA)

Delivery:

This activity is evaluated in conjunction with the first activity (theory) through coursework and exams.

Related competencies :

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.

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

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: 25h

Theory classes: 10h

Self study: 15h



Guided activities

Description:

Students will have to work on guided activities.

The structure to be followed:

Groups of 2 or 3 people with a maximum duration of two hours.

Discussion of the results obtained and the problems that have arisen during implementation.

Realisation of a report on the practice carried out with the results, questions and conclusions. This report will be evaluated together with the completion of the practice.

Specific objectives:

Consolidate the knowledge acquired in theory classes and practices.

Material:

Recommended bibliography. Notes from professor (copies and/or ATENEA)

Delivery:

Reports should follow guidelines given in class.

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.

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

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: 14h

Guided activities: 4h

Self study: 10h



Reduced scope work

Description:

Resolution of two problems based on situations posed by the professor.

Specific objectives:

Consolidate the knowledge acquired in theory classes and practices.

Material:

Recommended bibliography. Notes from professor (copies and/or ATENEA)

Delivery:

The report should follow guidelines given in class.

Related competencies :

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.

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

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: 12h

Self study: 10h

Theory classes: 2h



Broad scope work

Description:

Resolution of a problem based on situations posed by the professor or student.

Specific objectives:

Expand and consolidate the knowledge acquired in theory classes and practices.

Material:

Recommended bibliography. Notes from professor (copies and/or ATENEA)

Delivery:

The report should follow guidelines given in class.

Related competencies :

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.

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

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: 12h

Self study: 10h

Theory classes: 2h

Written test

Description:

Development of a written test of the course contents 1 and 2. It includes theoretical aspects and development problems.

Specific objectives:

Demonstrate the level of knowledge achieved in theoretical activities and problems.

Material:

Recommended bibliography. Notes from professor (copies and/or ATENEA)

Delivery:

The exam will be held freely and the statement delivered along with the statement duly filled in with the data required.

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: 22h

Theory classes: 2h

Self study: 20h

GRADING SYSTEM

Written tests (PE). 50%
Work performed individually or in groups (TR). 40%
Attendance and participation in practical activities (AP). 5%
Quality and performance of group work (TG) 5%

EXAMINATION RULES.

Here are the rules of the system for evaluating the educational activities of the course.

Written tests (PE).

There will be an intermediate evaluation and a final exam for the course. Students must complete both theoretical questions and problems related to the theoretical and practical content of the course. Reviews and/or claims regarding the examinations will be conducted according to the dates and times established in the academic calendar.

Work done individually or in groups along the course (TR).

Students must follow the instructions explained in class and contained in the file for the work that will be proposed to the student in relation to different teaching content of the course. As a result of these activities, students must submit a report (preferably in PDF format) to the professor, with the deadline to be fixed for each activity. The evaluation work will involve both its realisation and a possible defense.

Attendance and participation in classes and laboratories (AP).

The labs will be assessed both in their implementation and in the implementation of practical exercises that will be proposed; they can begin during the class schedule planned for this type of activity to be completed (if applicable) as an autonomous activity, following the instructions given in class. The results of practical exercises delivered to the teacher must follow the instructions given in class.

The evaluation of the practice will involve both its realisation and a possible defense.

Quality and performance of group work (TG).

The reports of practices and/or group work will be assessed individually on the oral defense if necessary or of any single group on the report.

BIBLIOGRAPHY

Basic:

- Çengel, Yunus A.; Ghajar, Afshin J. Transferencia de calor y masa : fundamentos y aplicaciones [on line]. 6th ed. México, Madrid: McGraw-Hill, 2020 [Consultation: 06/10/2022]. Available on: https://www-ingebook-com.recursos.biblioteca.upc.edu/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=10213. ISBN 9781456277215.
- Dossat, Roy J. Principios de refrigeración. México [etc.]: Compañía Editorial Continental, 1980. ISBN 9682602017.
- Kreith, Frank; Bohn, Mark S. Principios de transferencia de calor. 7a ed. Madrid: Cengage, cop. 2012. ISBN 9786074816150.
- Pita, Edward G. Principios y sistemas de refrigeración. México D.F. [etc.]: Limusa, 1991. ISBN 9681839692.

Complementary:

- Grimm, Nils R. Manual de diseño de calefacción, ventilación y aire acondicionado. Madrid [etc.]: McGraw-Hill, 1996. ISBN 8448106636.
- Kohan, Anthony Lawrence; Míguez Gómez, Claudio; Urcelay Azpitarte, Ramón. Manual de calderas : principios de operativos de mantenimiento, construcción, instalación, reparación, seguridad, requerimientos y normativas. Madrid [etc.]: McGraw-Hill, cop. 2000. ISBN 8448125460.
- Mills, Anthony F; Régules Ruiz-Funes, Sergio. Transferencia de calor. México DF [etc.]: Irwin, 1995. ISBN 8480861940.
- Ramírez Miralles, Juan Antonio; Miranda, Ángel Luis; Llorens, Martín. Nueva enciclopedia de la climatización. Barcelona: CEAC, 2000-. ISBN 8432965421.
- Márquez Martínez, Manuel. Combustión y quemadores. Barcelona: Marcombo Boixareu, DL 1989. ISBN 8426707718.



- American Society of Heating, Refrigerating and Air-Conditioning Engineers. The ASHRAE Handbook. Fundamentals.... Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, [1993?]-. ISBN 15237230.
- American Society of Heating, Refrigerating and Air-Conditioning Engineers. The ASHRAE handbook. Refrigeration.... I-P and SI ed. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2008-. ISBN 19307187.

RESOURCES

Audiovisual material:

- Notes made by the professors of the course. Resource
- Transparencies, proposed problems to be used in class. Resource