WEN613: Advanced Thermal Desalination

Program	Water & Environmental Engineering
Course Code	WEN 613
Course Title	Advanced Thermal Desalination
Credit Hours	3
Name of Faculty	Prof. Dr. Hassan E. S. Fath
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Course Description	The course describes the advanced science and technology of thermal desalination processes for fresh water production to overcome water scarcity and ensure sustainable fresh water supplies. It addresses technical and economical parameters of both commercial operating and new technologies. It covers also the recent developments, areas to enhance efficience, reduce water production cost and CO_2 emission. The course covers: i- Techno-economical study and analysis of conventional thermal technologies; MSF, MED and VC, ii- Hybrid, tri Hybrid and Integrated Technologies, iii- New and Promising Future Technologies Analysis (H-DH, MD), iv- Pretreatment and posttreatment systems (NF, UF and FO, NP, and IX), v- Power-Desalination Cogeneration Analysis, vi- Solar Desalination, vii- Nuclear Desalination, viii- Desalination related issues; scale, corrosion, material used and Brine Management and Environmental Impact and viii- Areas of Enhancing Desalination Processes Performance.
Pre-requisites	WEN 504 or equivalent.
Co-requisites	None
Course Objectives (Learning Outcomes of the course)	Upon successful completion of the course, the students will be able to: • Define the performance of different thermal desalination processes and the factors affecting them • Identify the areas of improving thermal desalination technologies' performance, specific energy consumption and water production cost. • Analyze and compare technically & economical the specifications and the performance of different thermal desalination technologies. • Develop and use of Different computer codes to analyze the thermal desalination performance • Carry out the detailed process design calculations and components sizing of the main thermal desalination processes • Read & assess the specifications of different operating thermal, hybrid and co-generation plants • Carry out pre-feasibility study on the techno-economics of desalination plant • Carry out detailed Analyze the coupling of alternative energy sources (solar and Nuclear) with thermal desalination processes.

Week	**Course Topics and Contents**
1	Review different desalination processes and mainly Thermal processes
2	Heat Transfer applications in Thermal Desalination (conduction / convection enhancement processes / fouling Factor)
3	Heat Transfer with phase change in Thermal Desalination (Evaporation, Boiling, and Condensation)

4	MSF systems; detailed description, Configurations, design and performance Analysis
5	Economical Analysis of MSF and water production Cost, and areas of Enhancing MSF plant performance (NEA, BPE, NCG,…)
6	Thermal / Mechanical Vapor Compression (TVC / MVC) process & Design
7	MED systems detailed description, Configurations, design and performance Analysis
8	*Mid semester break*
9	Economical Analysis of MED and water production Cost, and areas of Enhancing MED plant
10	Transient and Dynamic Study of Solar MED system
11	Hybrid, Tri hybrid, integrated processes and Cogeneration Plants
12	Thermal Analysis of Solar Thermal Desalination (Solar stills and HDH)
13	Thermal Analysis of Solar –Thermal Desalination (integrated Still-HDH and MD)
14	Integrated Nuclear - Thermal Desalination systems and Techno-economical Analysis
15	Related Problems and methods of mitigation (Scale formation, corrosion, materials selection, Brine Management and Environmental Impact)
16	*Final project presentations*

Relationship of course to program outcomes	
Program Outcome	Successfully demonstrate appropriate depth and breadth of knowledge that is at the frontier of their disciplines.
Program Outcome	Successfully use skills of interdisciplinary scholarship and research to integrate multiple perspectives.
Program Outcome	Understand and value diverse approaches to solving critical problems in research and to creating new knowledge judged by international standards.
Program Outcome	Work effectively in a multidisciplinary collaborative environment using highly developed cognitive and creative expert skills and intellectual independence.
Program Outcome	Communicate effectively, in written and oral forms, their research results and/or critique highly complex and diverse matters to diverse audiences.
Program Outcome	Use self-development for personal and professional improvement in their field and contribute to its future advancement.

Out – of – Class assignment	
Home Work	Home Work assignments, each is due at the end of each main topic of the course
Course Project	A report & presentation including literature survey, process design using computer programs for one typical operating (or new) desalination technology.

Course Grading	
Homework	20 %
Course Project	50 %
Final Exam	30 %
Total	100 %

Class/Laboratory schedule and Methodology	
Class	The class meets 15 weeks, 2 lectures per week, 75 minutes each.
Laboratory	Available computer programs and typical operating plants visits
Teaching and learning Methodology	A combination of white board use, Power-point slide presentation, and interactive class discussions to encourage student participation and enhance the learning. Real Plants and available pilots test unit will enhance the engineering process designs. Use of Different computer codes to analyze the thermal desalination plants' performance.

Course Materials	
Recommended Readings	The following reference texts will be made available to students through the library: • H. El-Dessouky & H. Ettouney," Fundamentals of Salts Water Desalination", Elsevier (2002). • El-Sayed, Y. M., and R. S. Silver, "Fundamentals of distillation", In: *Fundamentals of Desalination*, 2nd Edition, Vol. A, Spielger and Laird (Editors), Academic Press, 1980. • Ali El-Nashar "Multi Effect Distillation of Seawater Using Solar Energy", Nova Science Publishers, Inc. NY (2008). • Corrado Sommariva "Desalination and Advanced Water Treatment: Economics and Financing", Balaban Desalination Publications (2010). • Ettouney, H., and L. Rizzuti, "Solar desalination: A challenge for sustainable fresh water…", In : *Solar Desalination for the 21st Century*, L. Rizzuti and H. M. Ettouney (Editors), Springer, pp. 1-18, 2007. • DESWARE (Encyclopedia of Desalination & Water Reuse) • El-Dessouky, H., and H. Ettouney, "Flash desalination processes", In: *Heat Exchanger Design Handbook*, G. F. Hewitt (Editor), Begell House, New York, 2001. • Spielger, K. S. and Y. M. El-Sayed, "The energetics of desalination processes", *Desalination*, Vol. 134, pp. 109-128, 2001. • S.I. Sandler, *Chemical, Biochemical, and Engineering Thermodynamics*, 4th edition, Wiley, 2006. • Global Water Intelligence (GWI), Water Desalination Report (WDR) and www.DesalData.com • A. A. Mabrouk, Nafey A. S., and Hassan E. S. Fath. "Steam, Electricity and Water Costs Evaluation of Power Desalination Co-generation Plants", in press, Desalination & water Treatment (2010). • A. Mabrouk, Nafey A. S., H. E. S. Fath, " Thermo economical Design of a Multi Effect Evaporation – Mechanical Vapor Compression (MEE-MVC) Desalination Process", **Desalination, Vol. 230, Issues 1-3, pp 1-15 (2008).** • Hassan E. S. Fath and M. Ismail "Enhancing the performance of 2 x 5000 m3/day Sidi Krir MSF Desalination Plant", Proceedings of the EDS Conference, Greece, 22-25 April, Also Arab World Water (AWW), October issue (2007). • A. A. Mabrouk, Nafey A. S., H. E. S. Fath, , "Thermo-economic analysis of some existing Desalination Processes", **Desalination, 205, 354-373 (2007).** • A. A. Mabrouk, Nafey A. S., H. E. S. Fath,, "Analysis of a new design of a Multi Stage Flash – Mechanical Vapor Compression Desalination Process", **Desalination, 204, 482-500 (2007).** • Miller, J. E., "Review of Water Resources and Desalination Technologies", Report prepared by Sandia National Laboratories, SAND 2003-0800, 2003.

	• Wade, N. M., "Distillation plant development and cost update", Desalination, Vol. 136, pp. 3-12, 2001. • Ophir, A. and F. Lokiec, "Advanced MED process for most economical seawater desalination", *Desalination*, Vol. 182, pp. 187-198, 2005. • Hilal, N., H. Al-Zoubi, N. A. Darwish, A. W. Mohammad, and M. Abu Arabi, "A comprehensive review of nanofiltration membranes: Treatment, pretreatment, modeling, and atomic force microscopy", Desalination, Vol. 170, pp. 281-308, 2004. • Fath, H. E. S., S. M. Elsherbiny, A. A. Hassan, M. Rommel, Wieghaus, M., J. Koschikowski, M. Vatansever, "PV and thermally driven small-scale, stand-alone solar desalination systems with very low maintenance needs", *Desalination*, Vol. 225, pp. 58-69, 2008. • Alarcon-Padilla, D., J. Blanco-Galvez, L. Garcia-Rodriguez, W. Gernjak, and S. Malato-Rodriguez, "First experimental results of a new hybrid solar/gas muti-effect distillation system: The AQUASOL project, *Desalination*, Vol. 220, pp. 619-625, 2008. • Koschikowski, J., M. Wieghaus, and M. Rommel, "Solar thermal-driven desalination plants based on membrane distillation", Desalination, Vol. 156, pp. 295-304, 2003. • Koning, J.D., and S. Thiesen, "Aqua Solaris – an optimized small scale desalination system with 40 liters output per square meter based upon solar-thermal distillation, *Desalination*, Vol. 182, pp. 503-509, 2005. • Hasson, D., "Scale formation and prevention", In: *Scaling in Seawater Desalination: Is Molecular Modeling the Tool to Overcome the Problem?*, H. Galde and J. Ulrich (Editors), Shaker Verlag, 2001. • Pitzer, K. S., J. C. Peiper, and R. H. Busey, "Thermodynamics of aqueous sodium chloride solutions", *J. Phys. Chem. Ref. Data*, Vol. 13, No. 1, pp. 1-102, 1984. • Bromley, L. A., et al., "Thermodynamics of sea salt solutions", *AICHE Journal*, Vol. 20, No. 2, pp. 326-335, 1974. • Nuclear Desalination, IAEA publications. • Any other New thermal desalination publications (textbook(s), papers, patens, proceedings, …etc)
Instructional material and resources	Trip to local thermal / hybrid desalination plant(s).