MECH - 6095
Thermal Energy Storage

Course Description: Thermal energy storage devices are needed any time there is a mismatch between the supply (source) and the demand (need) of thermal energy. This course covers the fundamentals of thermal energy storage, from the concepts to the hardware, surveying the many different technologies found in current operation and select applications. Analysis is geared primarily at the senior-level undergraduate engineering students (having the usual background in the thermal science coursework) and first year graduate students. Several interesting case studies are examined as illustrative examples, along with a particular "class TES design project" to be assigned.

Prerequisites: Undergraduate thermodynamics, fluid mechanics, and heat transfer required, or equivalent. HVAC fundamentals / HVAC system design helpful, but not necessary.

Audience: Mechanical engineering students, and potentially any engineer, dealing with thermal energy systems and energy management. (To be offered on alternate year basis.)

Textbook: Not required. Extensive notes posted on BB website; daily agenda sheets updated weekly.

Reference TES Books:

1) Heat and Cold Storage with PCM: An up to date introduction into basics and applications, by H. Mehling and L. Cabeza, Springer, 2008; Available 24/7 free on line to all UC students through UC Eng. Library Springer's E-books collection.

2) Thermal Energy Storage, Systems and Applications by I. Dincer and M. Rosen, 2nd Ed. Wiley, 2010. The 2nd edition version we have on hand is as an e-book from Ebrary with single user access only (meaning that only one person can use it at a time). Hard copy of the *1st Edition* is on reserve in Engineering Library**.**

3) Sustainable Thermal Storage System, by Lucas B. Hyman, McGraw Hill, 2011.

4) Chapter 51, "Thermal Storage" found in 2012 HVAC Systems & Equipment Vol., ASHRAE Handbooks (latest version posted on BB). Was just updated in 2012.

In a Nutshell … … …Overall, this course can described as a TES survey class (35%), the relevant thermodynamics (15%), simple energy analysis using local utilities rate structure (10%), and the necessary detailed heat transfer analysis (40%) of sensible thermal storage tanks, heated planar slabs, and freezing & melting of PCM (required to predicts their performance) that is to be coupled/integrated into the building's cooling & heating system.

The three major reasons for using TES are: 1) to handle the inconsistency between the energy source and system load, 2) to save some real operating $$ (dollars) for the building owner, and/or, 3) to make a novel new product, and/or to accomplish a given task, that otherwise would not possible without the science of TES.

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20MECH6095. Thermal Energy Storage. 3 ug or gr.cr. Fundamentals of thermal energy storage, from concepts to the hardware, and different technologies in current use. Several interesting case studies are examined. Analysis and design of TES project. 3 lec.

Fundamentals / HT Modeling & Analysis

I. Basics Concepts and Terminology; Operating Strategies of TES Systems
Thermal Energy Storage Types: Sensible and Latent

II. Thermodynamics of TES and Comparison of Storage Materials

III. Economic Benefits of TES and Energy *Cost* Savings
Load-Shifting, Utilities and Building Owner Perspective
Capital and Operating Costs Considerations
Residential (RS vs.TD) and Commercial (DS, DP) rates

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IV. Modeling of Sensible TES Tanks - Mathematical formulation
Well-mixed (lumped) ; 1-D stratified *(briefly)*

V. Transient Analysis & Modeling of Heated Planar Slabs

VI. Analysis of Latent Phase-Change Heat Transfer (Freezing/Melting)
Stefan-type problems (exact solutions)
Idealized and approximate quasi-steady 1-D solutions

Technologies / Applications (Case Study)

- Equipment Hardware used for Building Cooling; CTES systems in Cincy

  - Cold TES (CTES) used in Air-Conditioning (Sensible – chilled water)
    Stratified tank (EPRI & ASHRAE Info), Vendor literature (CBI)
    Key technical papers, Engineering feasibility study (by ZBA)
    Tour of UC's Stratified Chilled Water tank (East Campus)

  - Cold TES (CTES) used in Air-Conditioning (Latent – Ice Storage)
    Vendor literature (BAC, Calmac, and others)
    Ice-on-tube research at UC

- TES used in Solar Applications
  Typical set-ups (Solar Decathlon '07), hot water tanks (vendor info)
  Solar ponds, Trombe wall, CSP

- Phase Change Material (PCM) as Energy Storage Material
  Suppliers of PCM material
  Augmentation techniques to increase k
  BioPCM "Green" board to increase building mass

- Thermal Energy Storage in Small Storage Containers and Novel Applications
  Two-lump (sensible) model & containers with PCM (latent)
  Examples - medical transport and for personal use (smart coffee cup)