Solar Thermal Energy Design and Solar Ponds

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ECE4833 Devices for Renewable Energy

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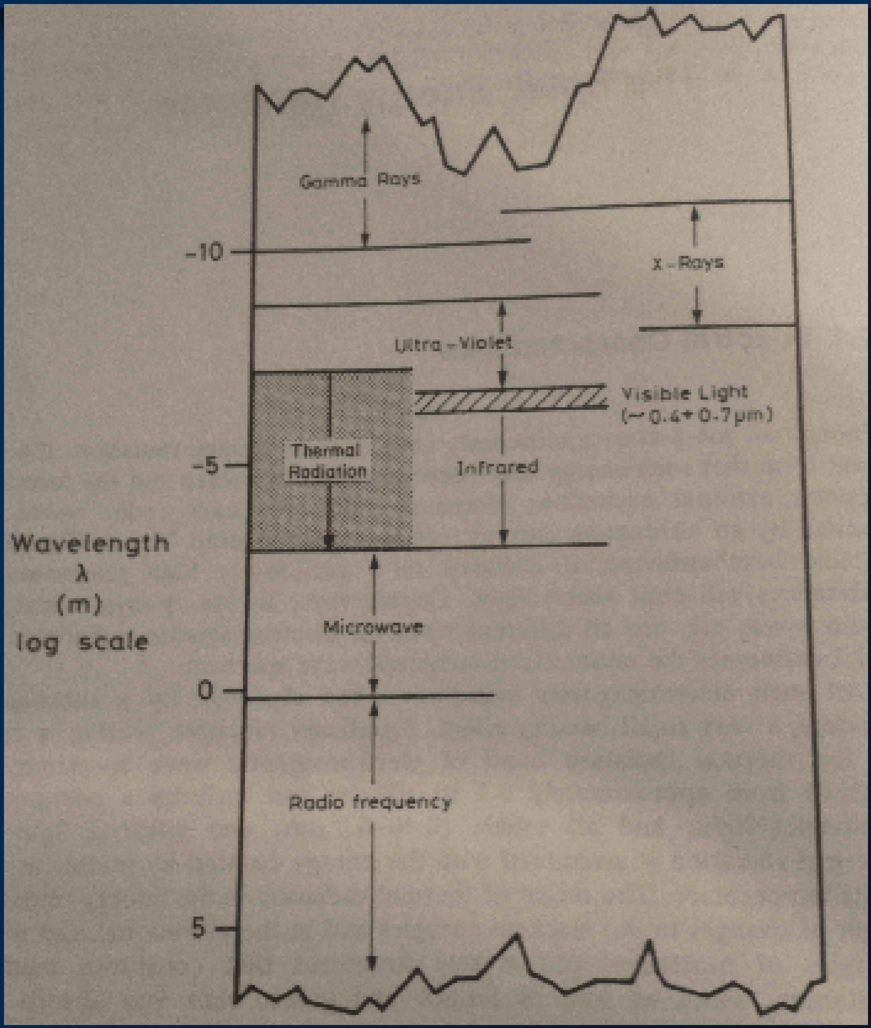
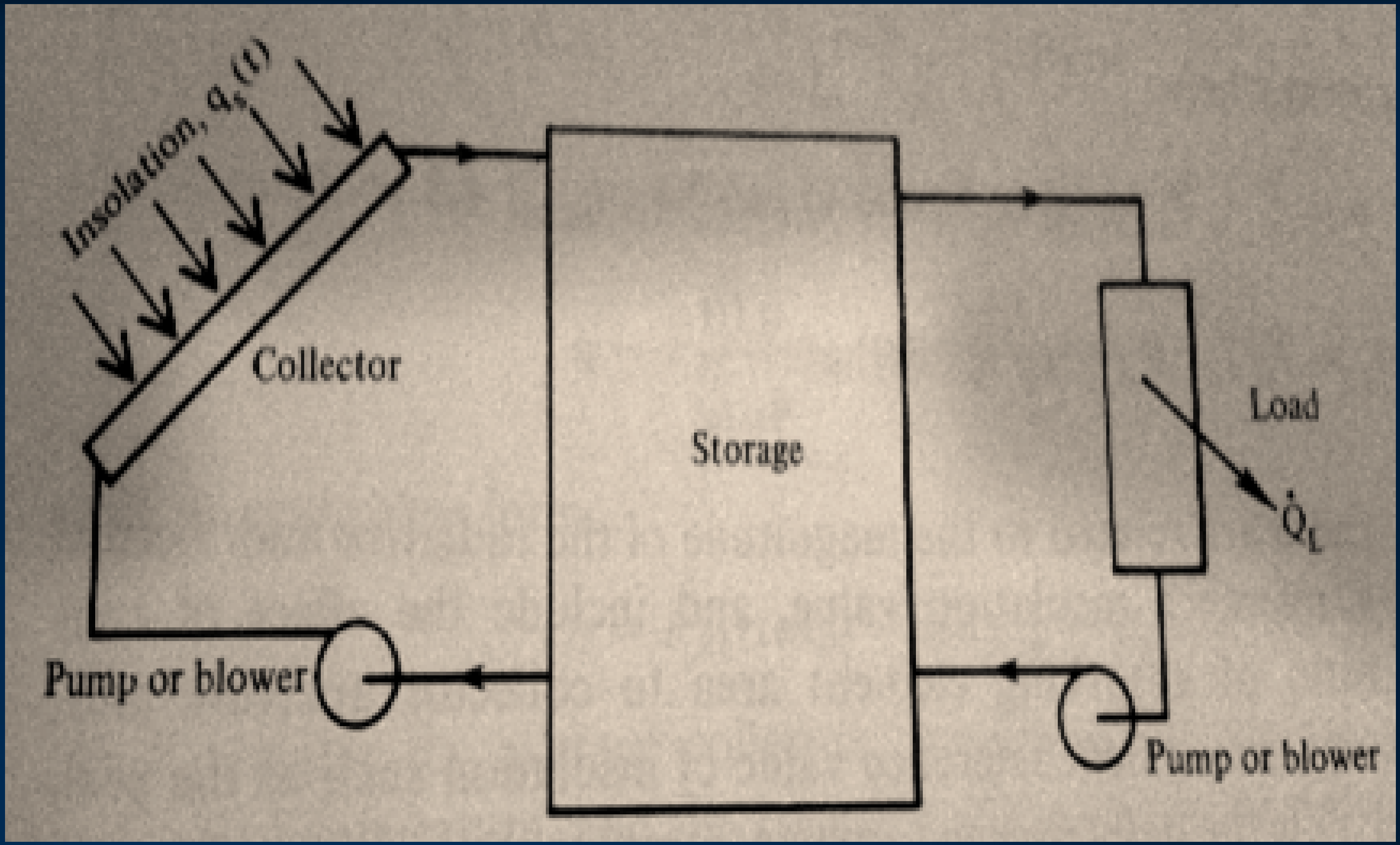
Solar Radiative Heat

- Confined to thermal radiation band of the electromagnetic spectrum
- .1-100um wavelength range



Norton (Page 6 Fig. 2.1.1)

Basic Solar Thermal Conversion Model



Howell (Page 21 Figure 2-1)

Collector Types

- Low Temperature: usually flat plate for heating pools
- Medium Temperature: usually flat plate for residential/commercial water heating
- High Temperature: mirrors and lenses used for electric power production

Low Collector

http://www.apowersolutions.com/commercial/solar-pool-heating/

Medium Collector

http://www.solartekdenver.com/Education.html

High Collector

http://www.energyc2.com/home/Solar%20Troughs.html

Collector

Solar Collector Efficiency Calculator:
http://andyschroder.com/solarradiation.html

- Geographical location of collectors; longitude and latitude
- Collector altitude and azimuth angle (fixed collector tilt)
- Collector surface area (m2)
- Collector performance characteristics obtained from third party test results
- Model assumes no shading or obstructions of the collector

Input

How much power do solar thermal collectors produce?

- When planning for a solar thermal system, it is critical to consider the available solar radiation at the installation site.
- Solar radiation is a highly variable power source. Radiation varies significantly from hour to hour, day to day, and location to location, based upon time, weather and geographic region.
- It is critical to note that solar thermal collectors have a variable efficiency, dependent upon solar radiation intensity, fluid temperature, and air temperature.
- **Contrary to photovoltaics**, using average radiation for an entire month **will not** accurately predict output of solar thermal collectors.
- In order to more accurately predict solar collector output a numerical model has been developed which simulates the power output of solar thermal collectors using hourly solar radiation and temperature data from NREL. This takes into account the variation in efficiency of the thermal collectors, accurate to the hour.
- Please use the form below to specify the details of your configuration.

Collector Make/Model	Theoretically Perfect Collector (no heat loss, optical loss, etc)	If you don't believe that the CPC1518 is the best collector for your application, choose another make/model and see how the simulation results compare.
Collector Inlet Temperature (Tin):	50 Degrees C	Recommendations: 50C (Domestic Hot Water, DHW), 30C (Radiant Heating), 80C (Absorption Cooling)
Collector Outlet Temperature (Tout):	60 Degrees C	Recommendations: 60C (DHW), 40C (Radiant Heating), 100C (Absorption Cooling)
Altitude Angle (Collector Tilt):	0 Degrees (horizontal)	
Azimuth Angle (direction the collector is pointing):	0 Degrees (Due South, assuming the Altitude Angle is Positive)	
Location:	GA - ATLANTA HARTSFIELD INTL AP (Class 1)	Choose from 858 locations throughout the United States of America. Class 1 locations utilize higher quality input meteorological data than class 2 locations.
Number of Days to Average:	365	Increasing the number of days averaged will result in a smoother power curve, however, an appropriatly sized thermal energy storage device is required in order for the smoothed results to be physically realistic.
Choose the area in which the results will be presented with respect to:	◉ Per Square Meter (Gross Collector Area) (useful for comparing collectors of different sizes) ○ Per Collector	

Perform Simulation

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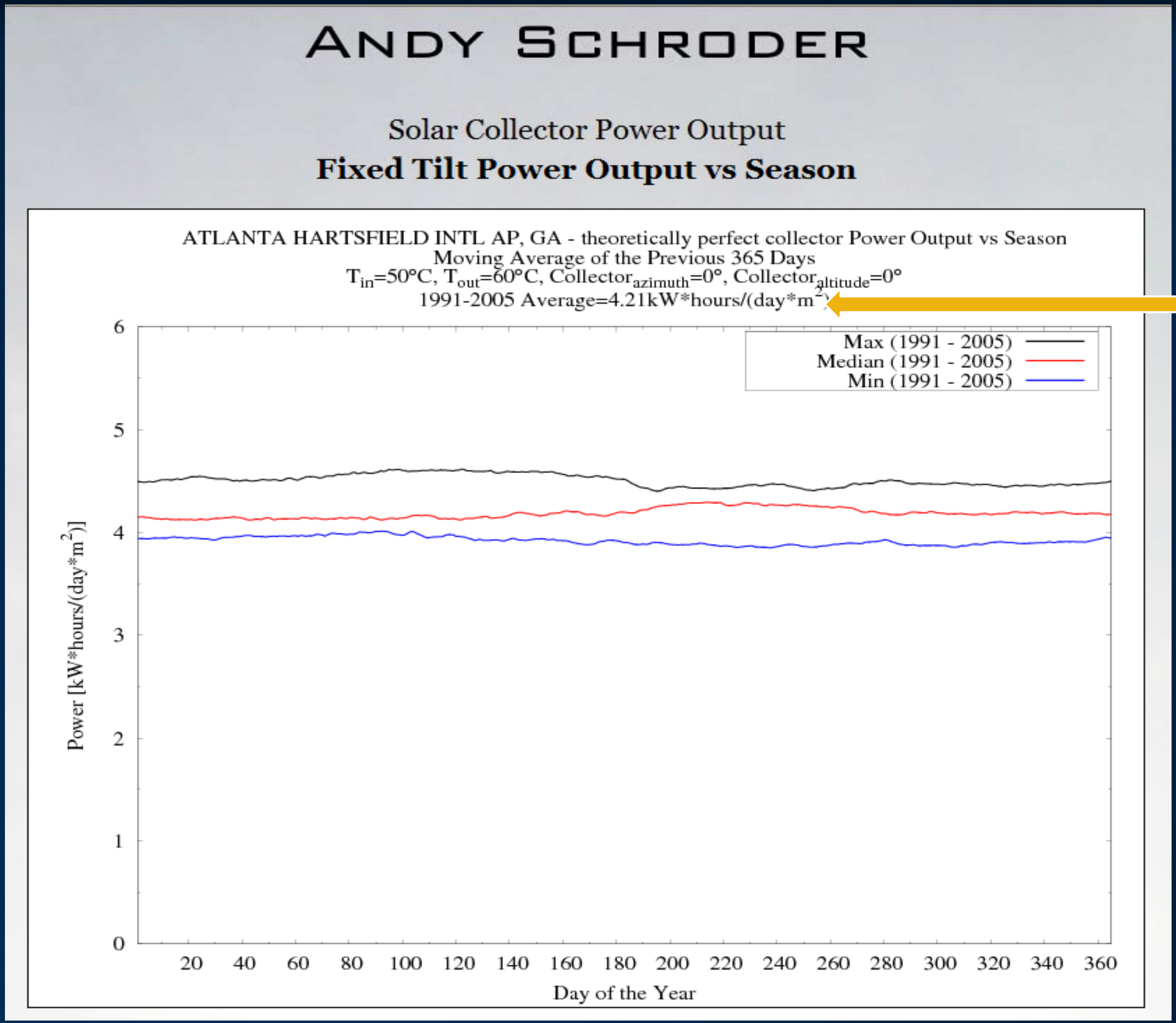
Output

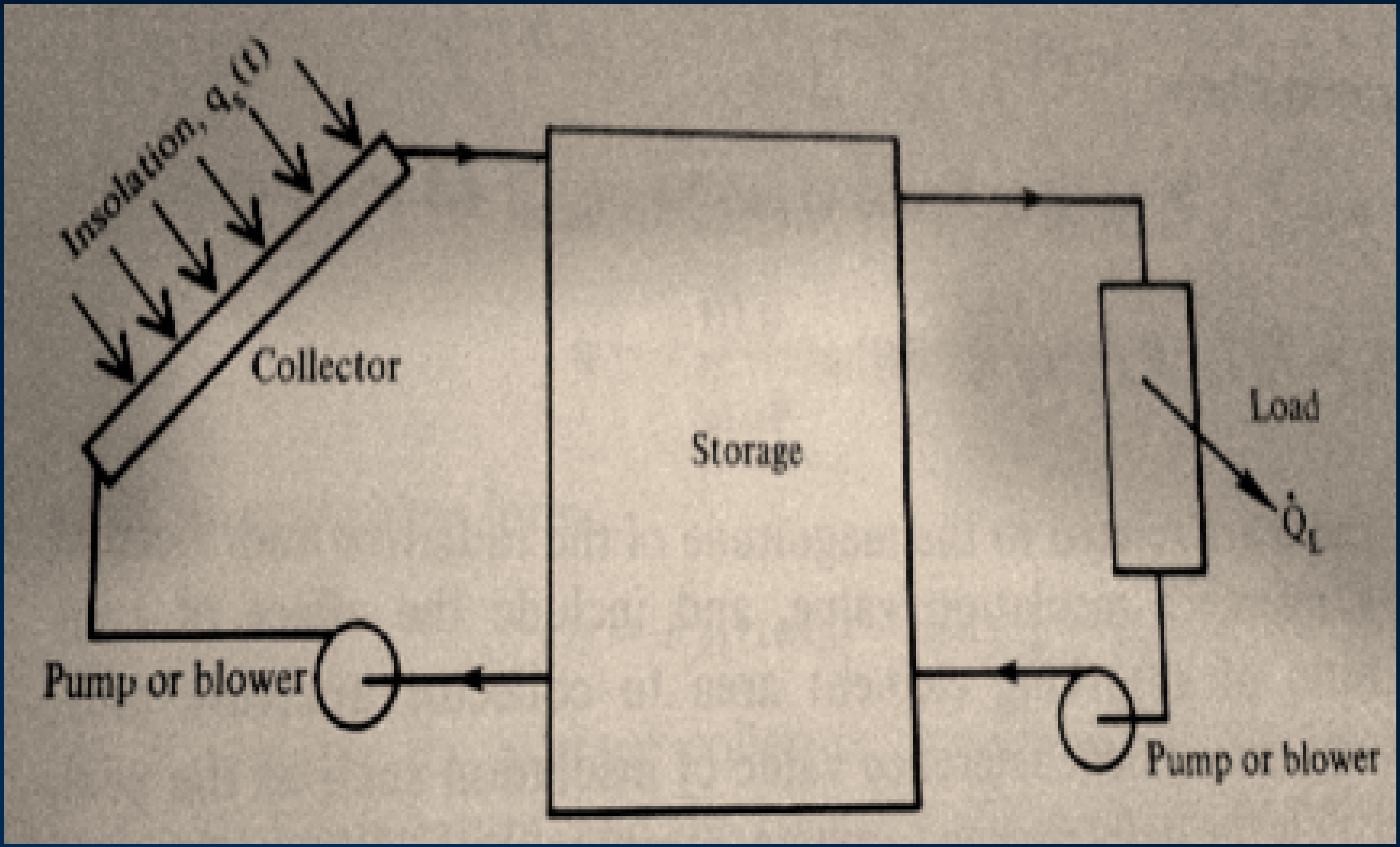


Average output

Storage

- Stores energy collected during day to be used at night
- Sometimes collection system can also act as storage system
- Storage material
  - Stable
  - High specific heat
  - High density
  - Generally use water, rock, and/or salts

Basic Solar Thermal Conversion Model



Howell (Page 21 Figure 2-1)

Conversion Model Equation

- Useable Energy Factors:
  1. Absorption efficiency of insolation
  2. Convection of ambient air thermal loss
  3. Radiative exchange with surroundings thermal loss

$$Q_u(t) = (\tau\alpha)_{eff} q_s(t) A_c - UA_e(T_e - T_a) - \varepsilon_{eff}\sigma A_e\left(T_e{}^4 - T_a{}^4\right)$$

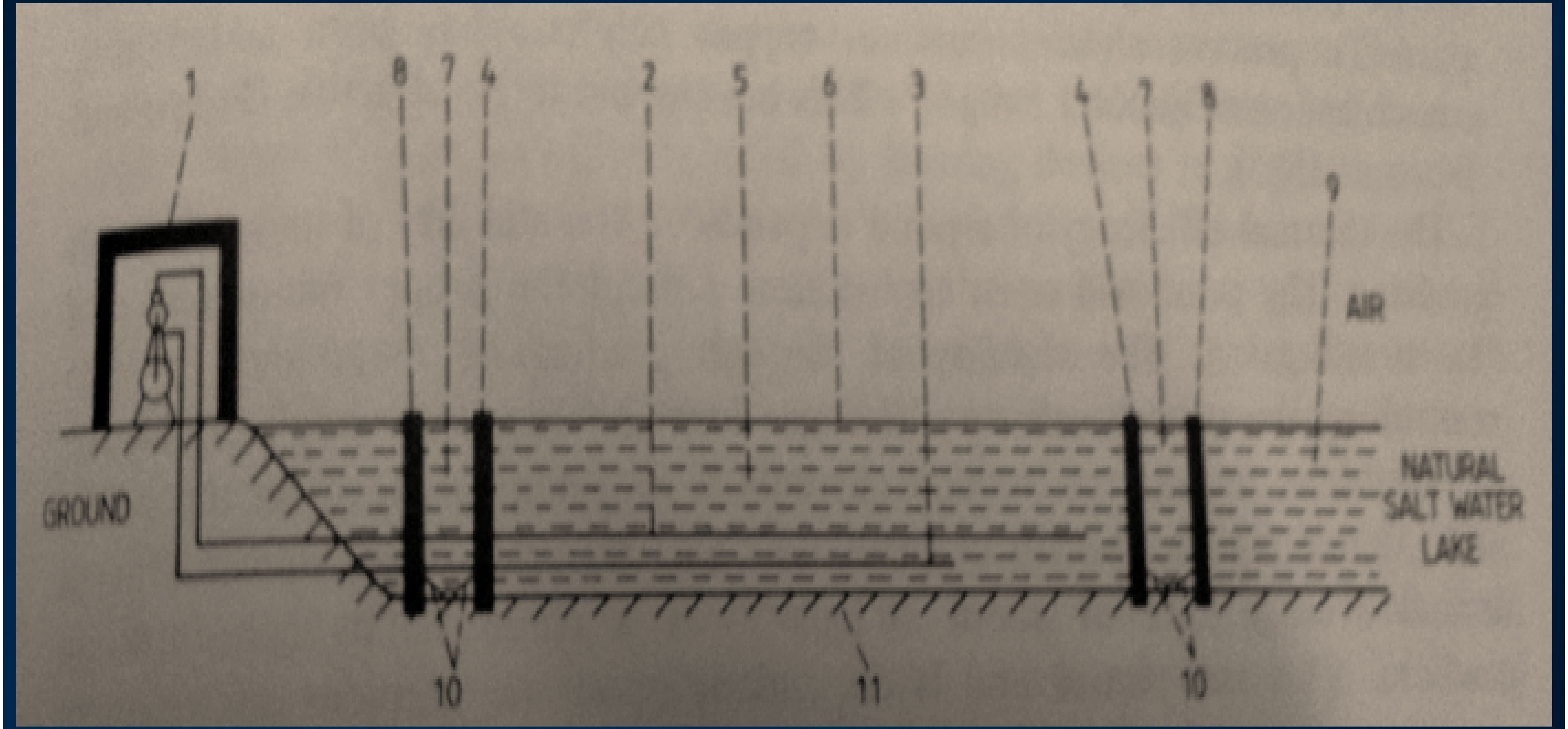
Derivation in Howell (Page 21 Equation 2-1)

- Questions about solar thermal conversion?

Solar Pond- University of Texas El Paso (1986)

http://www.infinitepower.org/projects.htm

Implementation



Norton (Page 153 Figure. 9.2.3)

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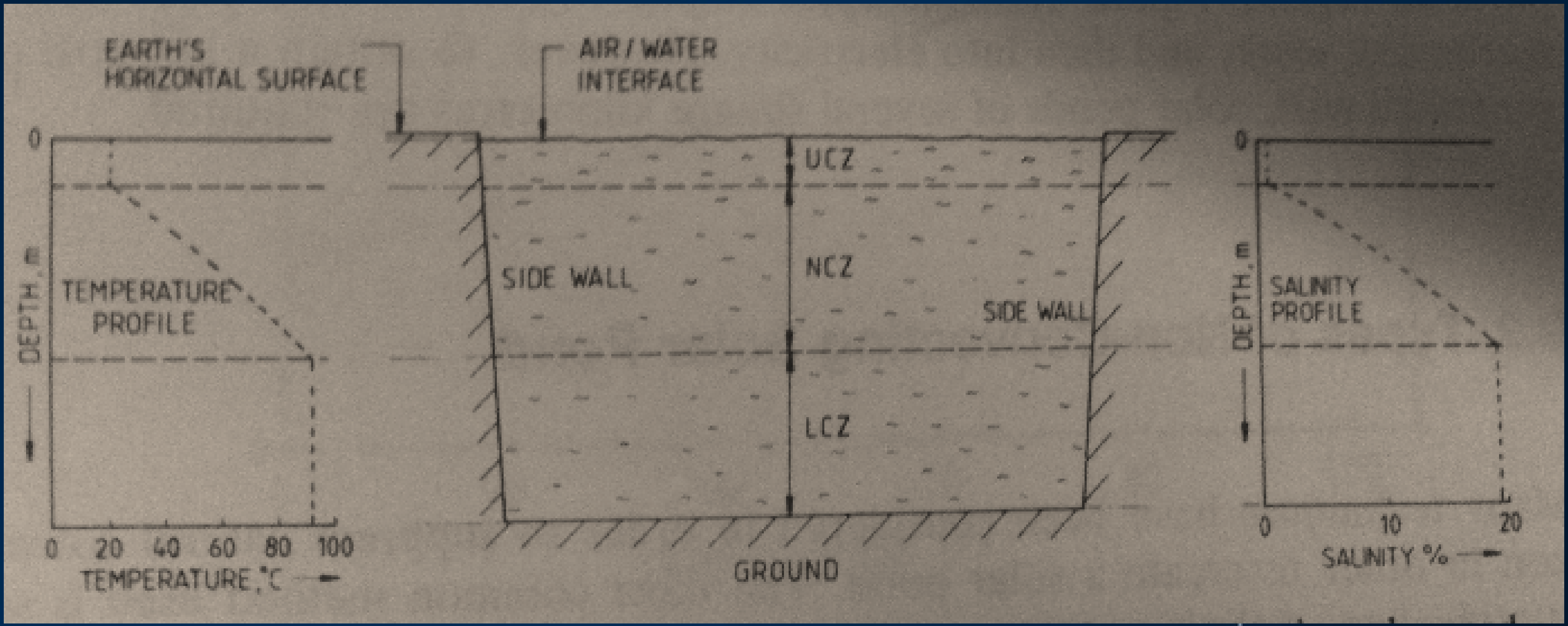
Practical Use of Solar Ponds

- Some salt-gradient ponds occur naturally
  - The “hot lake” in Orville, Washington
  - Lake Vanda, Antarctic
- Some created
  - Ohio State University, 2.5m depth, 200m^2
- Convert pond heat to mechanical work, then to electricity with use of a Rankine cycle engine
- Low cost per watt requires km^2 pond size

Solar Pond Collection/Storage

- Acts as both a collector and heat store
- 3 Layers
  - Upper-convecting Zone (UCZ)
  - Non-convecting Zone (NCZ)
  - Lower-convecting Zone (LCZ)

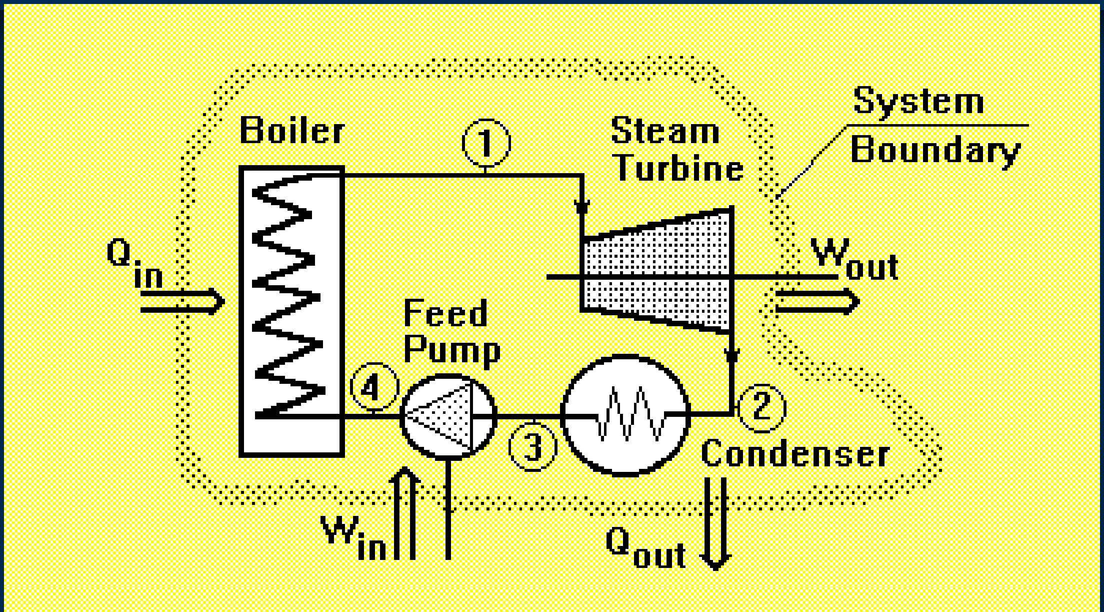


Norton (Page 149 Figure. 9.1.1)

Maintaining the Salt Gradients

- Controlling salinity difference between layers
- Inhibiting internal convection in the NCZ
- Limit growth of UCZ from salt diffusion upwards
- Surface flushing
  - Reduces UCZ temperature and counter balances evaporation
- Wind Barriers
  - Helps prevent surface layer mixing and limit growth of UCZ

Rankine Cycle Engine



Four Step Process:

1. Working fluid (generally water) put under high pressure
2. Boiled to a dry saturated vapor
3. Dry vapor expands through steam turbine, creating power
4. Wet vapor put through condenser and becomes saturated liquid

http://www.taftan.com/thermodynamics/RANKINE.HTM

References

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- Questions or Comments?