An Efficient Solar Thermal-Powered Evaporation System for Salt Harvesting and Wastewater Treatment

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Research—Innovation—Education

UC Solar in Mongolia

Project Background

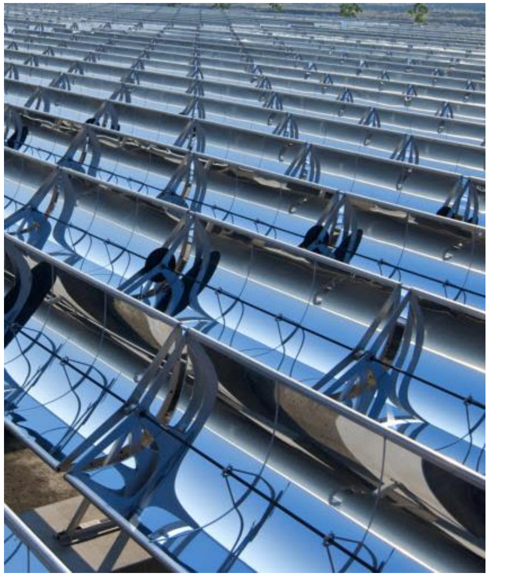
- Wastewater evaporation is a proven method for reducing the water portion of water-based waste streams

Project Background

- Evaporation systems are widely used by the manufacturing and food processing industries for the treatment of "adverse" wastewater
  - To reduce the water content of waste prior to shipping it for offsite disposal
  - To reduce the water content of reverse osmosis and desalination/distillation waste streams (brine)
  - To recover distilled water (condensate)
  - To reclaim valuable dissolved solids
- However, these systems are energy-intensive and are powered exclusively by fossil fuels

Project Background

- To substitute solar energy for fossil fuels, evaporation systems require input temperatures in excess of 150^{o}C ("process heat")
- There are commercially-available solar thermal systems that produce these temperatures, but they have significant drawbacks, including:
  - Requiring tracking, which reduces system reliability and increases maintenance costs
  - Stringent installation requirements
  - Don't perform well on hazy or partially cloudy days
  - High cost (~$2,000 per kWt installed)

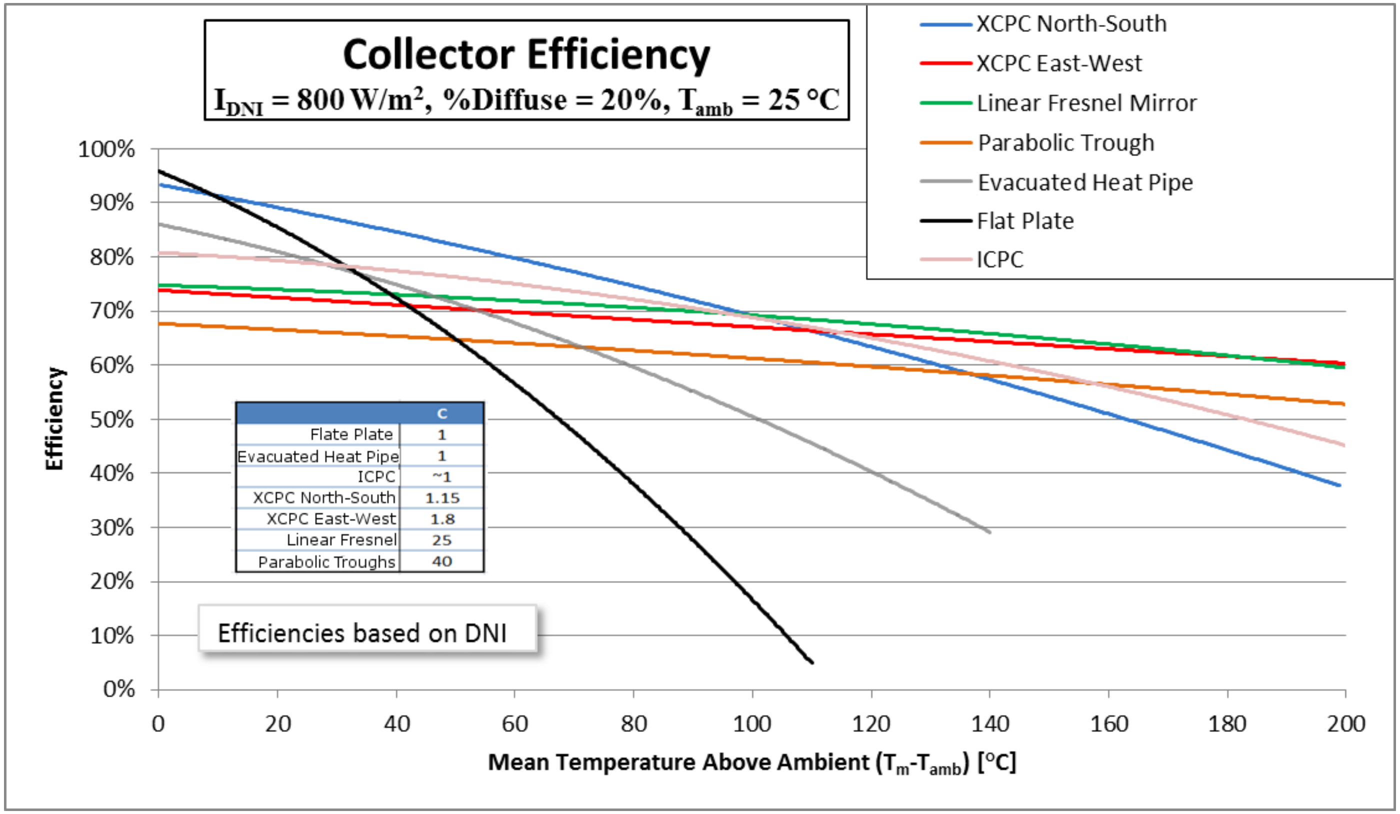


The XCPC

- With CEC support, researchers at UC Merced have designed, tested and demonstrated the External Compound Parabolic Concentrator (XCPC), a novel non-tracking solar thermal collector for industrial process heat (100º-250ºC)

The XCPC

- The XCPC matches the performance and efficiency of tracking solar thermal collectors

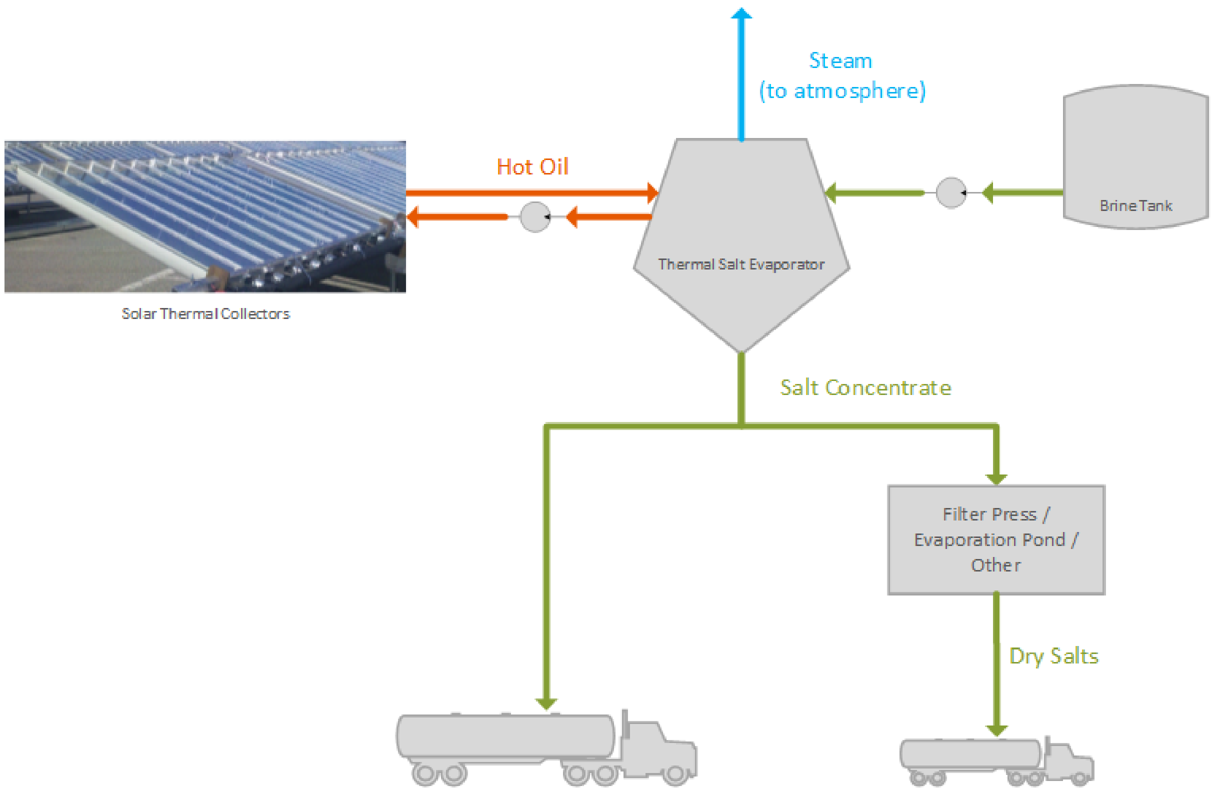


The XCPC

- For the past three summers, the XCPC has been powering the UC Merced Solar Cooling Demonstration Project
  - 160 north/south XCPCs
  - 50 sqm aperture area producing 19 kWt at >165ºC
  - 6.5-ton Broad double-effect absorption chiller
  - Direct solar-powered cooling for six hours per day (plus two hours extended cooling)

Evaporation Project Overview

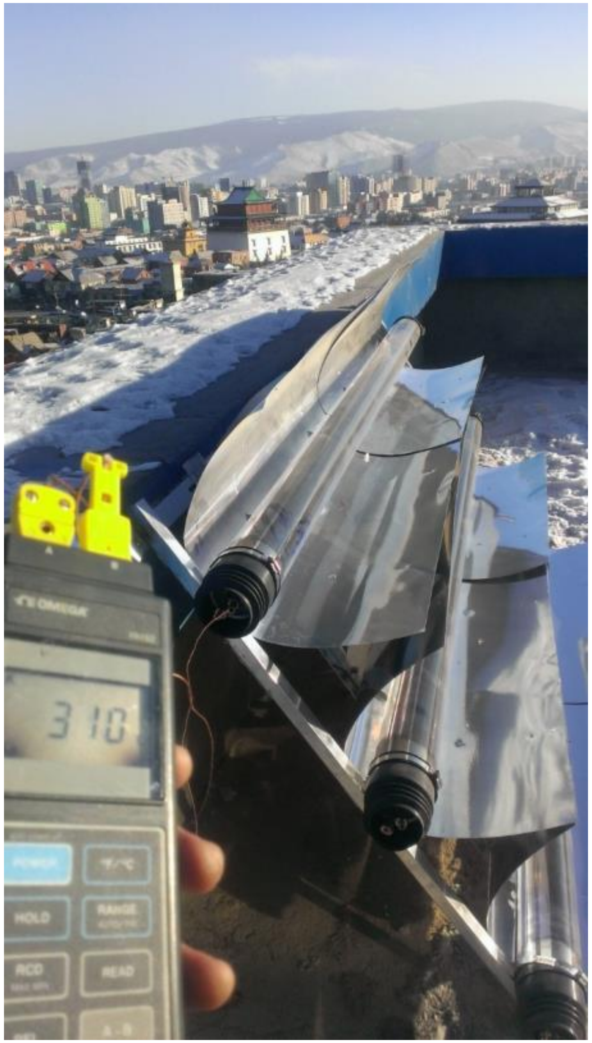
- This project will combine the XCPC technology with a commercial evaporator to create an efficient solar thermal-powered evaporation system

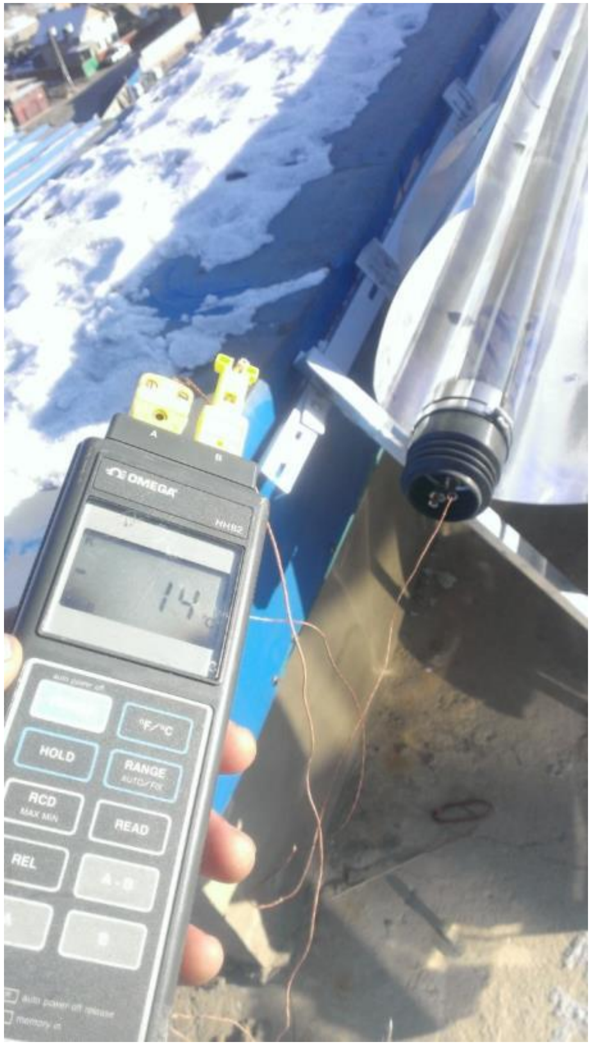


Evaporation Project Overview

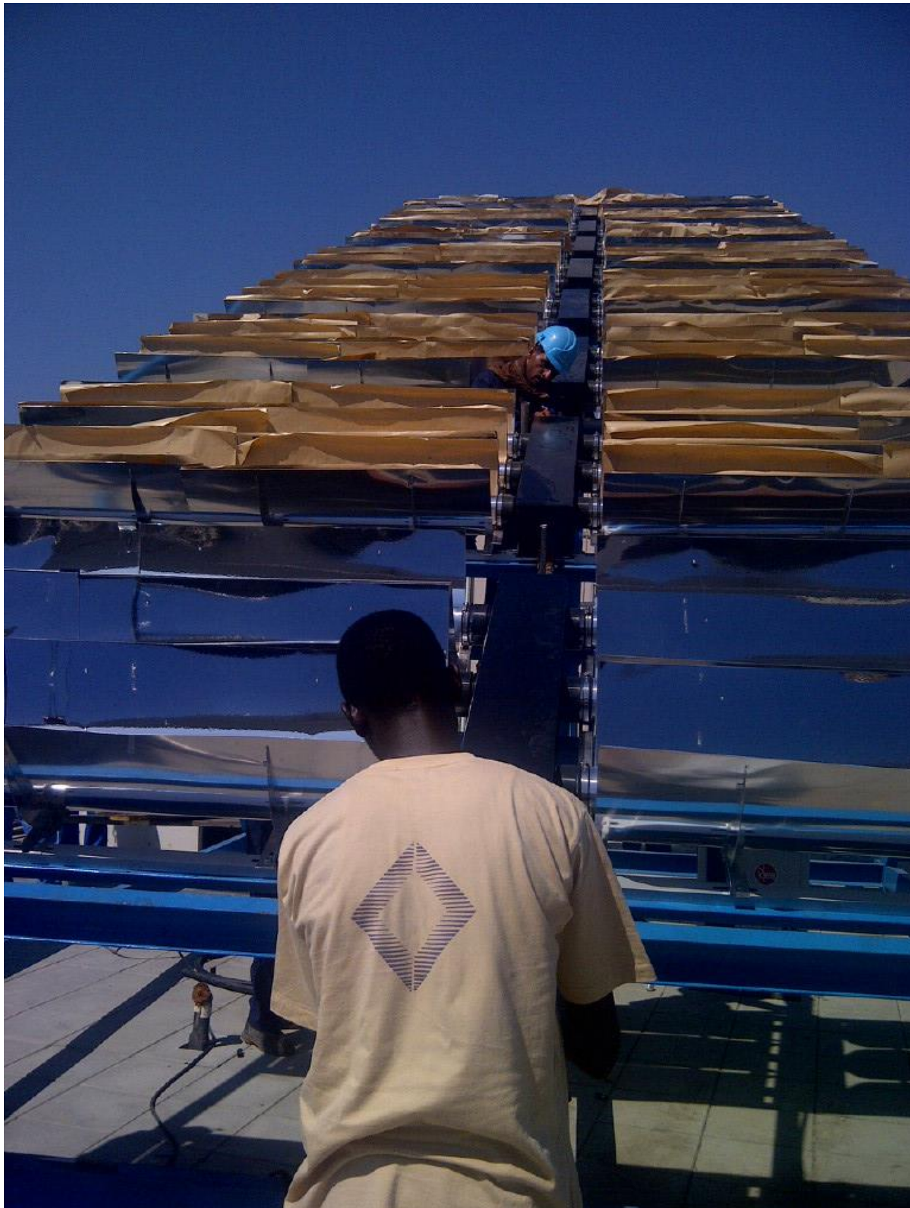
- Funded by the CA Department of Water Resources Prop. 204 Drainage Water Re-use Program
- Demonstrate the ability to directly power a 10 gph capacity thermal evaporator using UC Merced's XCPC technology
- Test the system's effectiveness in processing a variety of Central Valley waste streams, including:
  - Reverse osmosis and desalination/distillation waste streams (brine)
  - Industrial and food processing waste streams
  - Agricultural drainage
- Study the economic and environmental benefits of solar-powered evaporation

Mongolia -- Initial Testing



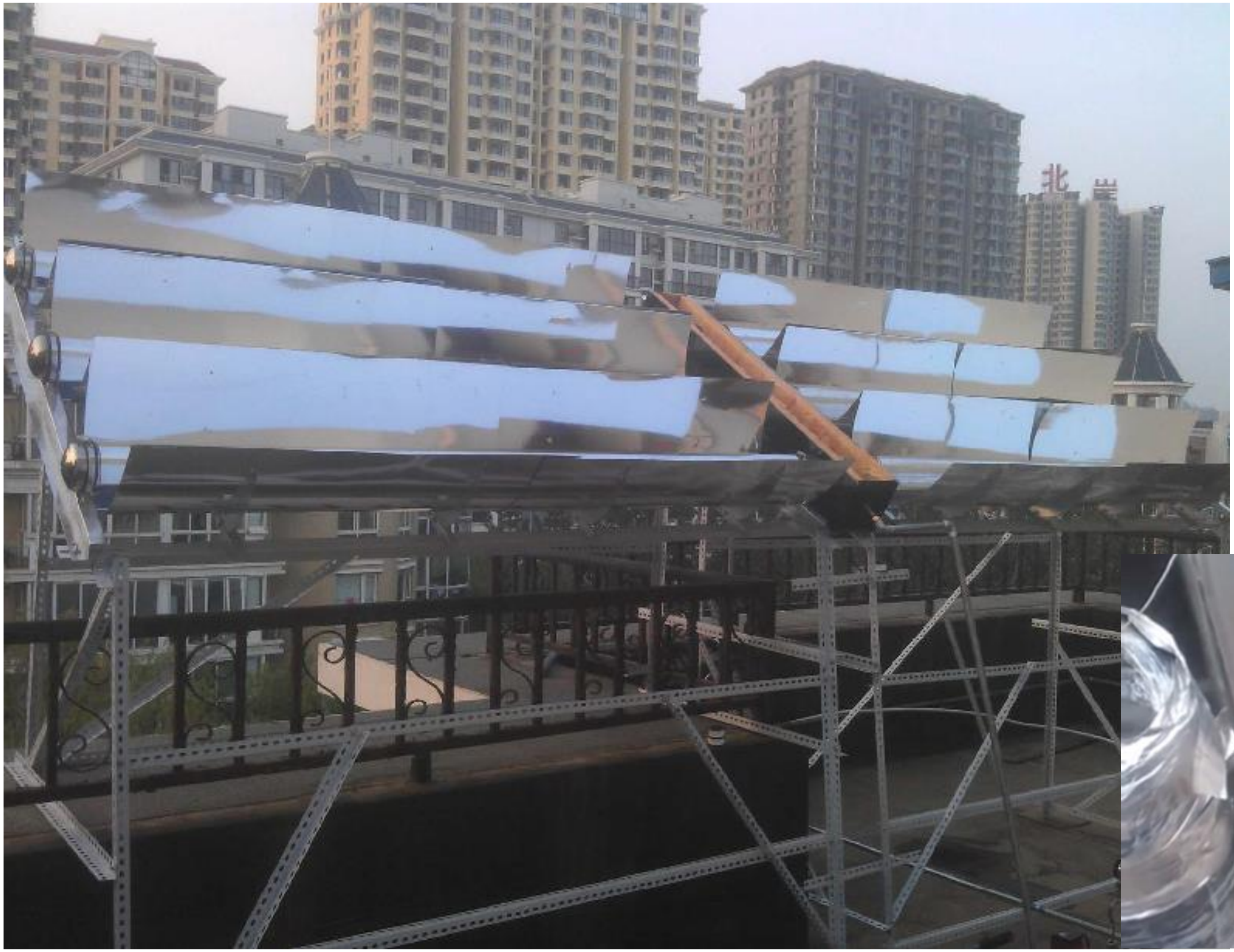


Al Khaleej Sugar Refinery in Jabel Ali
Largest Sugar Refinery in the World

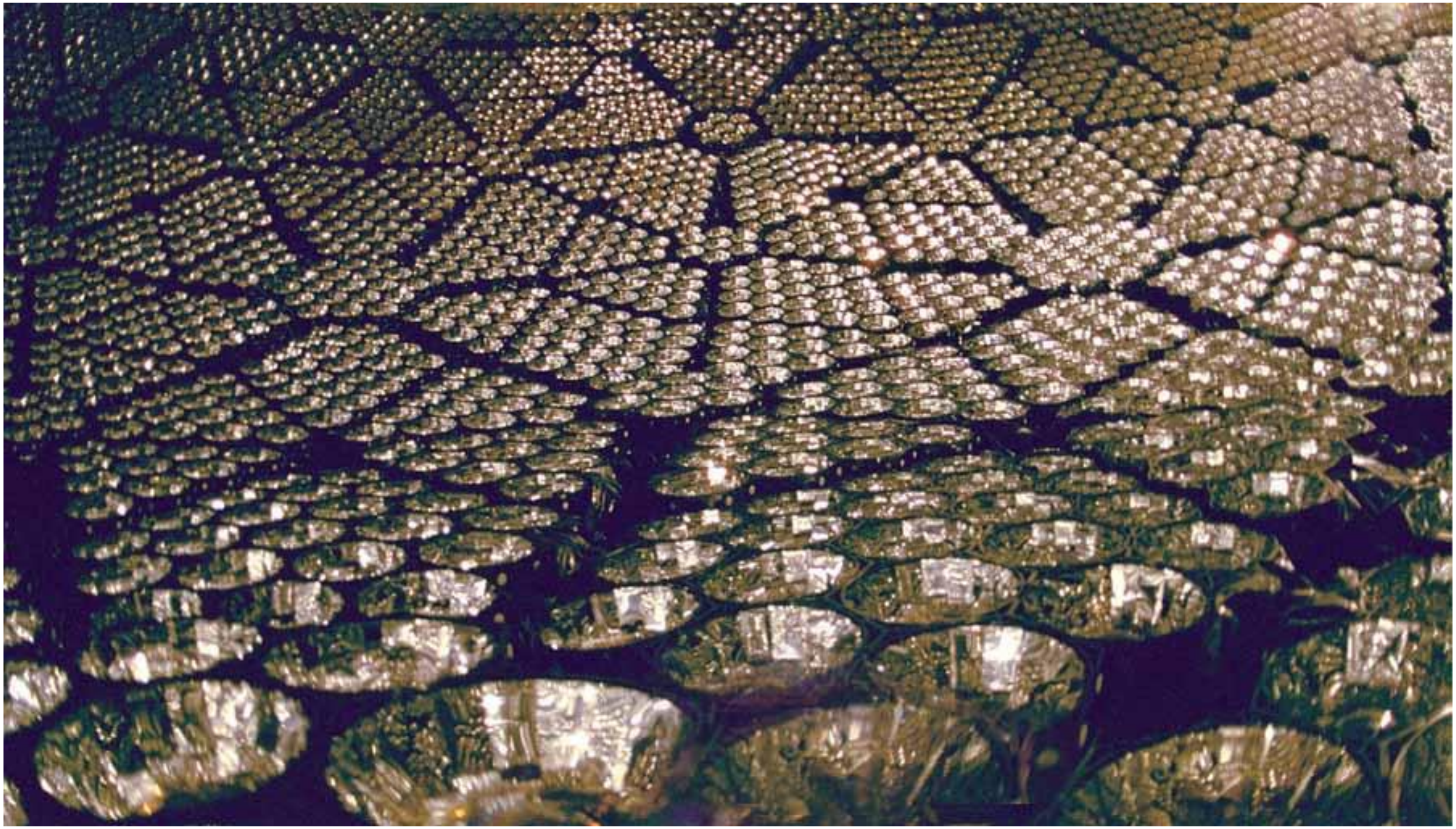



SS-500s

Steam Generation in Beijing



Neutrino and Nonimaging Optics



Deuterium and MSF

SUMMARY

Distributions of deuterium in two multi-stage flash plants and a multi-effect plant were calculated by use of a numerical model. The calculated values were in good agreement with the observed ones. The maximum error was less than 1 %. Product water of high deuterium concentration can be obtained from the distillation chamber at the highest temperature with a high concentration factor. The deuterium concentration in the product water was around 155 ppm.

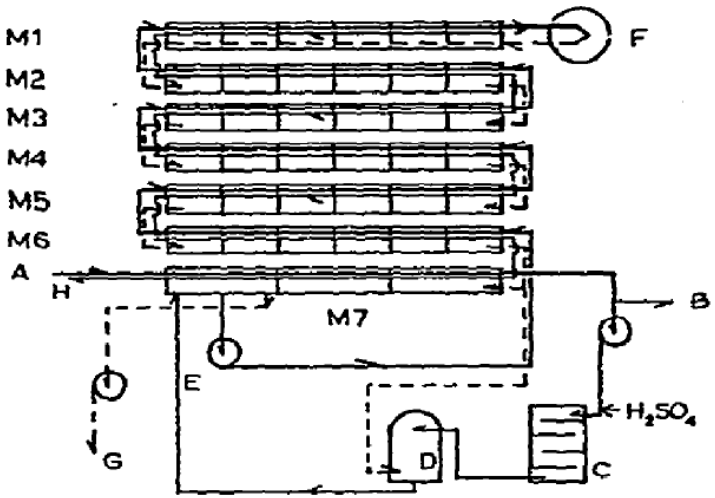
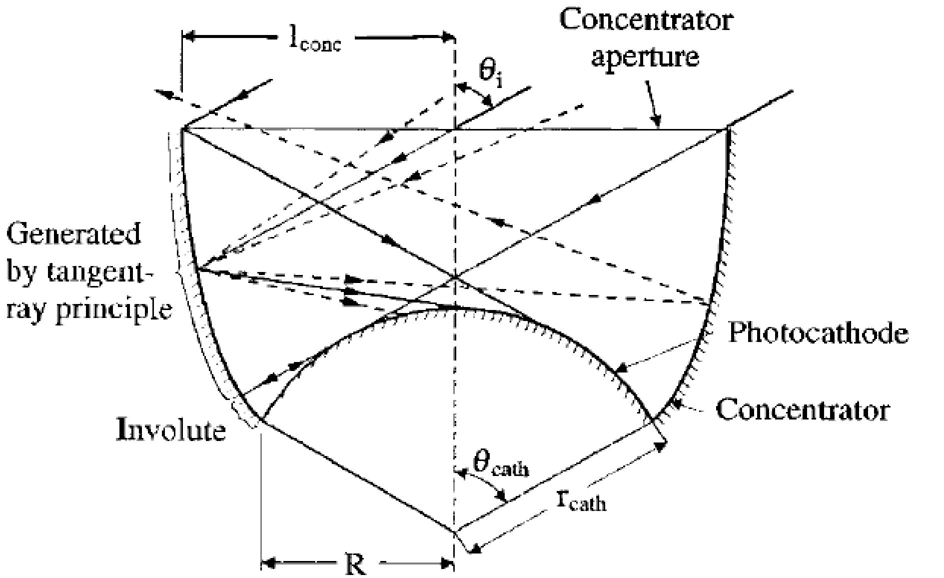


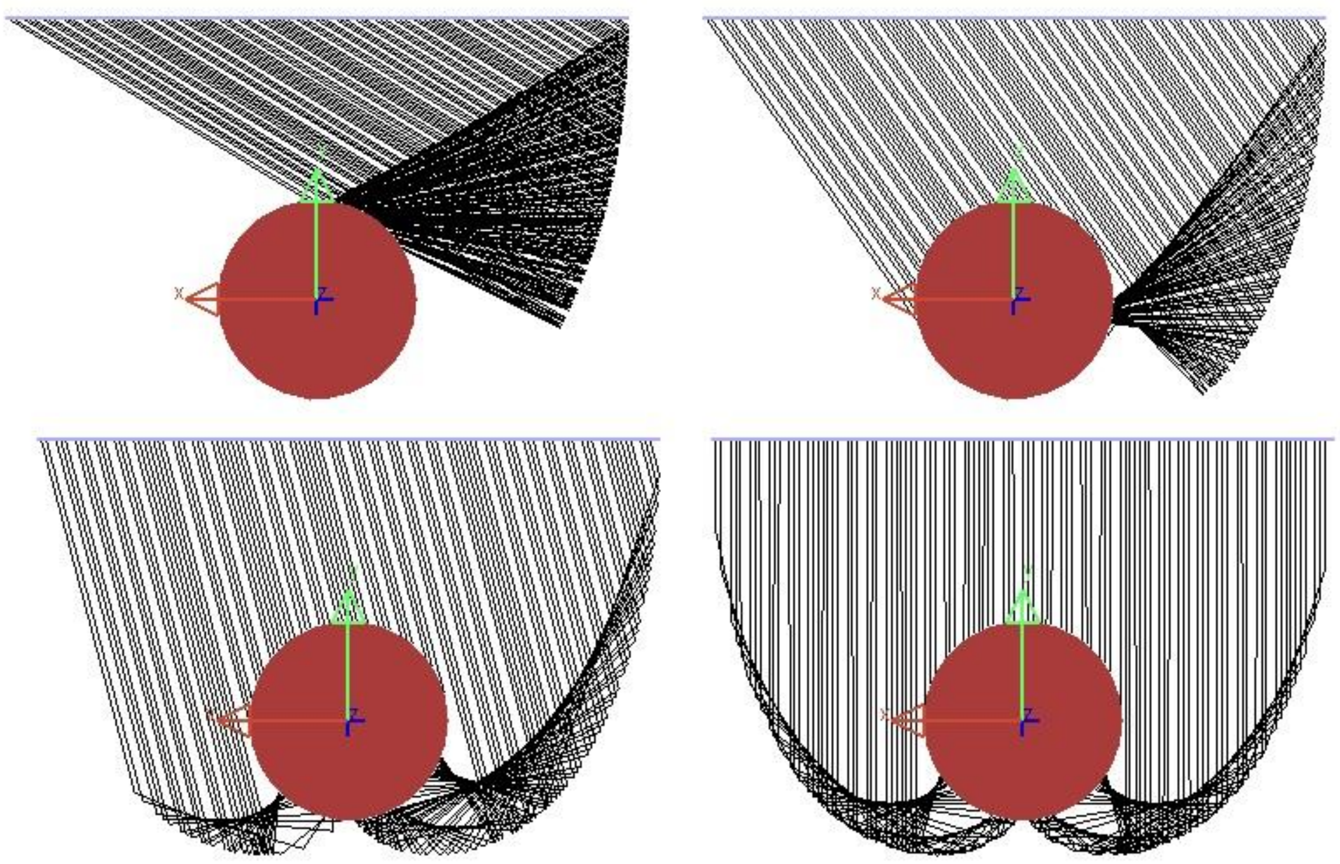
Fig. 1. Flow diagram of the MSF test plant (a 39-stage flash evaporator). A: Feed seawater; B: Seawater discharge; C: Decarbonator; D: Degasifier; E: Brine recirculation pump; F: Brine heater; G: Brine discharge; H: Product water; M1-M6: Heat recovery section; M7: Heat rejection section.



l_{conc}
θ_i
Concentrator
aperture
Generated
by tangent-
ray principle
Photocathode
Concentrator
Involute
θ_{cath}
r_{cath}
R

The XCPC

- The XCPC uses non-imaging optics to track the sun, while the XCPC hardware remains stationary



Challenges for Brine Evaporation and Salt Harvesting

- Agricultural drainage and wastewater streams vary in composition

-- different concentrations of dissolved species, metals, contaminants

-- recovery value versus disposal costs variable

- Different salts have different solubilities as a function of temperature (T) and pressure (P)

-- precipitation and dissolution of salts varies with T, P

-- salts will precipitate at different stages from different water compositions

-- unwanted precipitation causes scaling and fouling

- Evaporation is more energy intensive as volume of water decreases and concentration of salt increases

-- Zero-liquid discharge (ZLD) is difficult and expensive to achieve

✱ Need to know the geochemical composition of the water in order to optimize evaporation and harvesting processes

Major Ions in Water

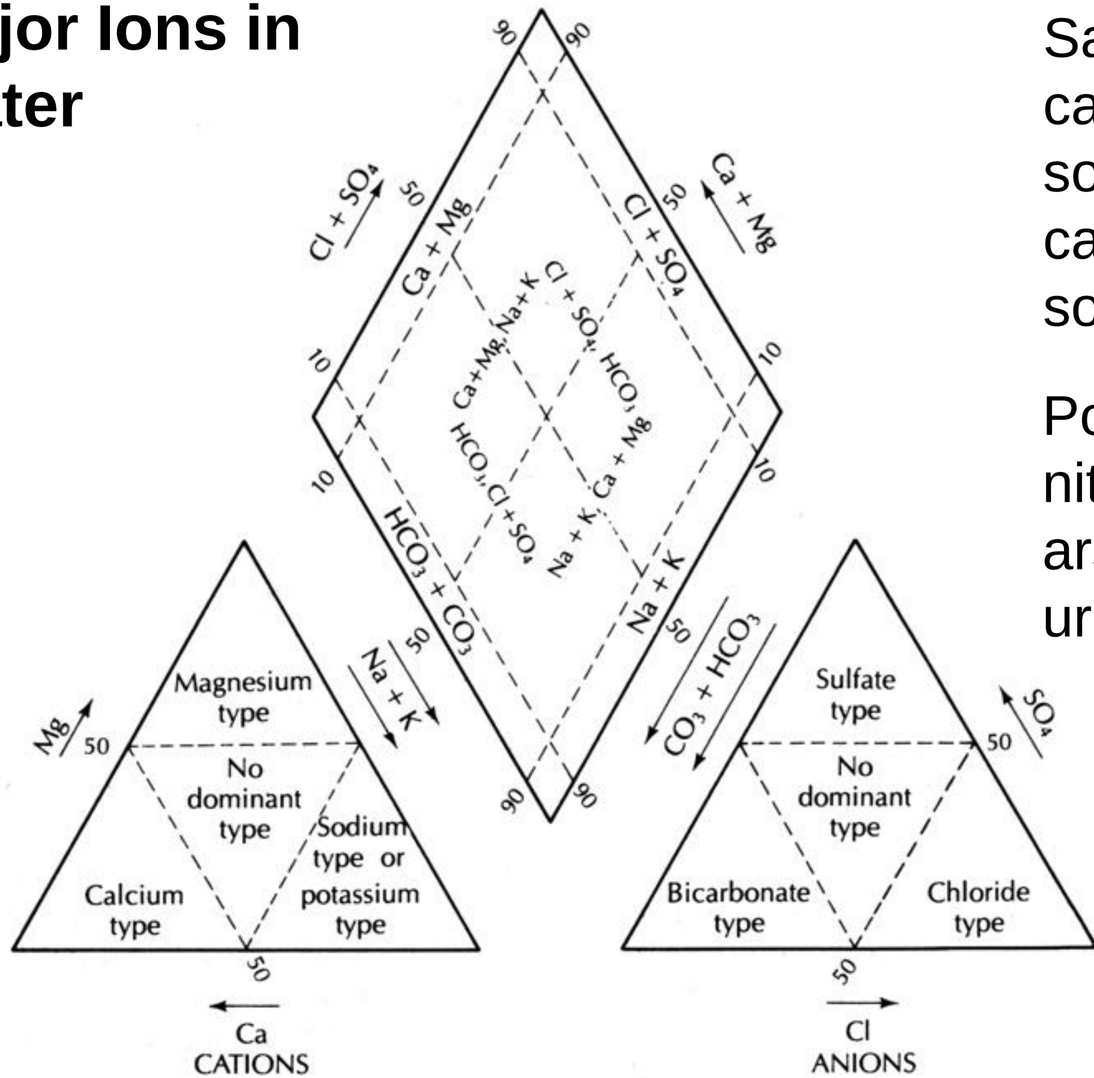


FIGURE 10.9 Hydrogeochemical classification system for natural waters using the trilinear diagram. from Fetter, C.W. (1994) Applied Hydrogeology

Salts
calcium sulfate
sodium sulfate
calcium carbonate
sodium chloride

Possible contaminants
nitrate, selenium, arsenic, chromium, uranium

Possible fouling
silica, organics

Opportunities for Technology Innovation

• Different salts have different solubilities as a function of temperature (T) and pressure (P)

-- use thermodynamic-kinetic-transport modeling to theoretically optimize T and P conditions to control precipitation of specific phases

-- test theoretical models in pilot-scale experiments to refine model parameters under dynamic conditions

-- iteratively link theory and experiments

• Agricultural drainage and wastewater streams vary in composition

-- initial analyses and calculations to identify valuable or problem constituents

-- real-time monitoring, system optimization, and dynamic feedback

-- high-purity separation of precipitated salts; minimize solid waste

• Evaporation is energy intensive

-- solar XCPC evaporator to generate high temperatures

-- integrated temperature control and system optimization

Contact Us

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