A Low-Cost Heliostat Design

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Solar Cooking Perspective
Problems

- Solar energy is plentiful, but very diffuse
- Concentrating systems provide higher energy levels for wider applications
  - Traditional Rankin Steam Cycles
  - Sterling and Other Heat Engines
  - Concentrating Photovoltaics
  - Air Conditioning
Problems

- Increasing energy costs make all solar applications more viable
- But-- there is still a significant cost differential between delivered solar energy, and traditional sources
- We must close this cost gap in order for solar technology to gain widespread acceptance
Heliostat Development Goals

- Achieve “best cost” design for a concentrating heliostat
- Progression
  - Stretched membranes possibly offer the lowest cost method of reflecting sunlight
Heliostat Development Goals

- Stretched membranes are not new,
  - First patents for solar applications date back to 1962
  - Many others have moved the art forward, but there have been problems
    - Expensive and heavy support structures
    - Wrinkling of film
    - Thermal stability
    - Vacuum overhead
    - Scaling
    - Cost
    - Weather ability
      - UV, rain, wind, abrasion resistance
      - Catastrophic Wind and Hail Events
Heliostat Design Elements

- Frame - providing
  - a raised planar surface for the attachment of the film
  - clearance for vacuum deformation

Cross-Sectional View

Reflective film

Simple Ring

Sealing Film

Drum-Type design offers more depth for film deflection
Problem- simple ring or drum tends to oval under load, or it’s own weight
Design Solution - Structural Foam Board Backplane

Structural foam board backplane
Prevents ovaling of ring,
And minimizes the depth required for film deformation

PVC piping ring prevents warping,
or “potato-chipping” of foam board

Patent pending
With Application of vacuum, the structural foam board backplane becomes slightly concave, increasing The strength of the total assembly
Design Elements

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Heliostat Design Elements

– Film Wrinkling
  • Reflective film tends to wrinkle badly as the vacuum deforms it into a concave shape
Heliostat Design Elements

– Film Wrinkling
  • Solution is a floating batten that stops the inward propagation of the wrinkles.

* Batten depicted on the outer surface of the film for clarity

Dish with floating battens attached to the inner surface of the reflective film.
Heliostat Design Elements

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Heliostat Design Elements

– Thermal Stability
  • Reflective film has a different coefficient of expansion than the supporting ring.
  • Film gets loose when exposed to temperatures lower than those at which it was stretched.
Heliostat Design Elements

– Thermal Stability
  • Solution is solar heating of the support ring
  • Since a heliostat is intended to always face the sun, this heating is always at work

Solar radiation

Cross-Sectional View

- Heat Absorbing Layer
- Reflective Film
- Insulating Layer
- Conductive foil layer
- Support Ring

Structural Foam board

• Patent pending
Heliostat Design Elements

– Thermal Stability
  • 26 degree F ambient temp.
  • RH dish w/o solar tensioning
  • LH dish with solar tensioning

*Solar tensioning works only with sunlight

• Patent pending
Heliostat Design Elements

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Heliostat Design Elements

• Vacuum Overhead
  – Stretched membrane systems require a vacuum to focus light
  – Energy required to establish and maintain a vacuum must be subtracted from the total energy generated
  – Leakage rates average 1 foot loss of focal length per 30 minutes
  – No measurements of vacuum pump energy requirements have been taken, however

• One advantage of vacuum systems is once the vacuum is released, the dish returns to a safe flat mirror state
Heliostat Design Elements

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Heliostat Design Elements

- Scaling
  - 4’ diameter dishes are currently manufactured in low volumes.
  - 8’ diameter prototype is in testing
  - 10’ diameter is feasible.
Performance

- Performance of 8’ diameter dish
  - 1250 F maximum temperature
  - @ 850 W/M² Solar Insolation
Performance

• Receiver Test Rig
  – Heating water in Insulated pot
  – Type K Thermocouple
  – Daystar meter
ASHRAE Standard x580

\[ W = (T_f - T_i)MC_v/S, \]

- \( W \): Watts
- \( T_f \): Final Temperature
- \( T_i \): Initial Temperature
- \( M \): Mass of Water + Mass of pot
- \( C_v \): Specific heat of water and pot
- \( S \): Seconds
Heliostat Design Elements

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Heliostat Design Elements

– Material Cost
  • 4’ diameter dishes are currently manufactured in low volumes
  • Material cost is $24/M²
  • 8’ diameter prototype material cost is $35/M²
– Labor hours are currently very high, but the design is suitable for high-volume manufacture
  • Powered rotary fixtures
  • Combining multiple operations in each revolution
– Weather able film will increase material cost significantly
Heliostat Design Elements

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Heliostat Design Elements

- Weather ability
  - All current dish materials are weather able, except reflective film (polyethylene)
    - PVC lined foam board
    - Silicone and polyurethane sealants
  - NREL’s Advanced Materials Group is conducting accelerated life testing on film materials. 10 year life may be possible.
  - No reflective film is likely to survive major wind and hail events.
    - Tracking mechanism with redundant stowage modes
      - Active mode initiated by anemometer/wind direction
      - Breakaway weathervaning mode
Weathervane Mount - Single Heliostat
Weathervane Mount-Dish/Engine Arrangement

- multiple dishes

receiver

tracking structure

wind
Heliostat Design Elements

– Plan Moving Forward

• 7/06- Look for a test partner to verify performance
• 10/06- construct 8’ dish with weather able film
  – Begin outdoor testing
• winter 06/07- Design dish/engine mechanism
  – Tracking
  – Stowage
• Spring 07- construct and test 10’ prototype
• Summer 07- begin construction of dish/engine components
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