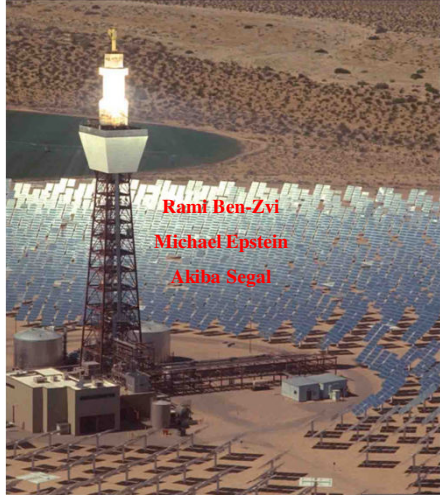


### Simulation of an Integrated Solar Steam Generator

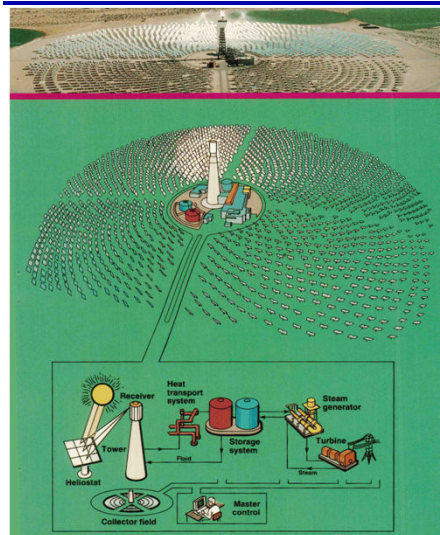


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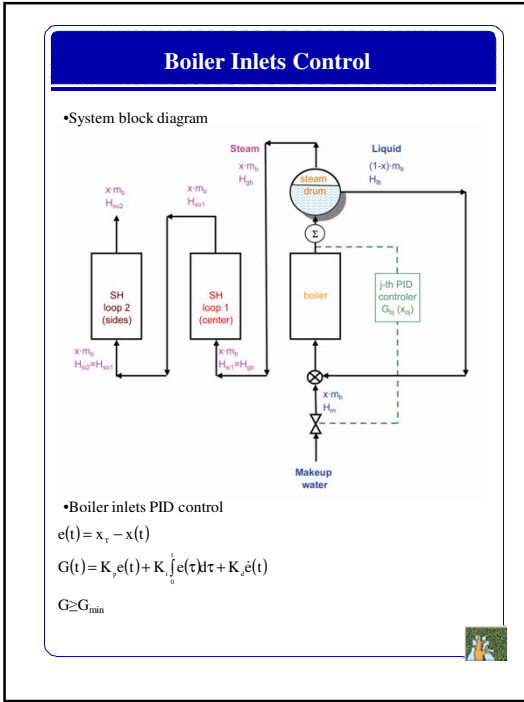
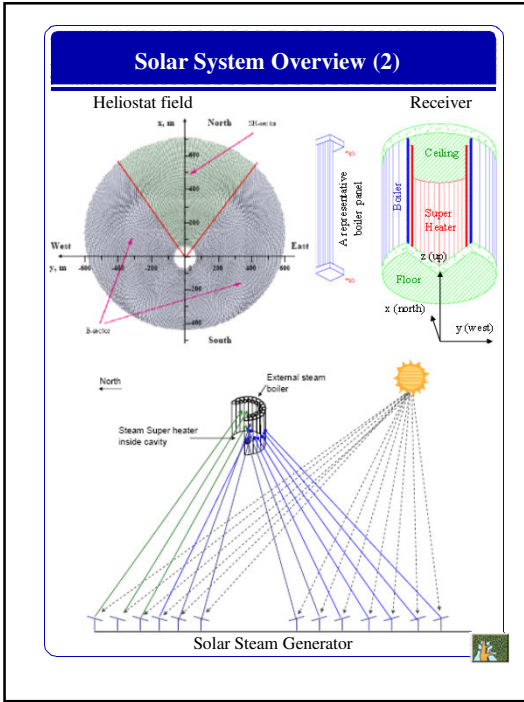
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### Solar System Overview (1)



Barstow Solar-II





### Properties

**Boiler:** SA-192 (carbon steel)

$\sigma_{\text{ensile}}$  = 325 MPa  
 $\sigma_{\text{yield}}$  = 180 MPa  
 $T_{\text{allowable}}$  = 510C = 783K

**SH:** SA-213TP304H (18Cr-8Ni)

$\sigma_{\text{ensile}}$  = 517 MPa  
 $\sigma_{\text{yield}}$  = 206 MPa  
 $T_{\text{allowable}}$  = 760C = 1033K

•The pipes are coated with a high-temperature black coating (Pyromark,  $\epsilon = 0.95$ )

**Insulation:** Kaowool / DuraBlanket / DuraBoard (ceramic)

Typical values used:  
 $k = 0.1 \text{ W/m-K}$   
 $\epsilon = 0.2$

**Steam:** Wagner's IAPWS-95 package

### Critical Heat Flux (CHF) (1)

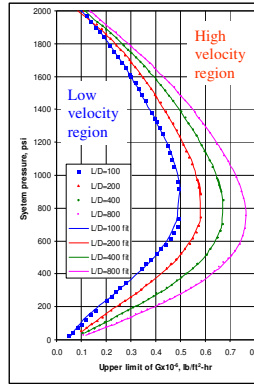
L.A. Payan-Rodriguez *et al.*, *International Journal of Thermal Sciences* **44** (2005) 179–188.

Water flow boiling patterns.

Sublayer dryout model

## Critical Heat Flux (CHF) (2)

B. Thompson and R.V. Macbeth, Boiling water heat transfer burnout in round tubes: a compilation of world data with accurate correlations. *AEW-R356* (1964).



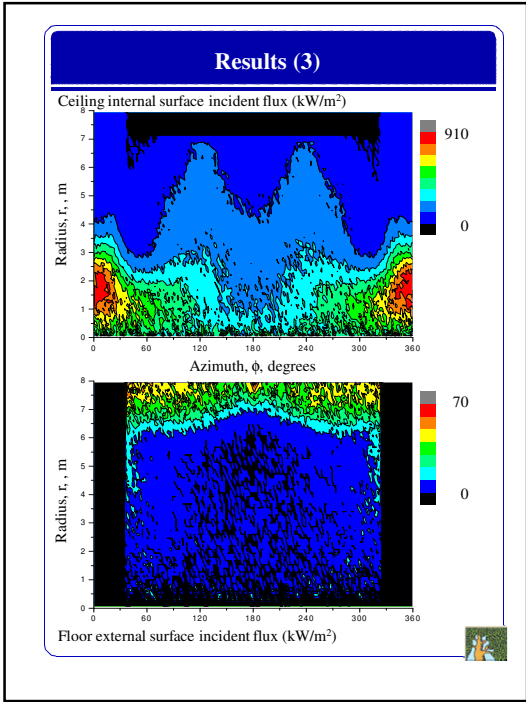
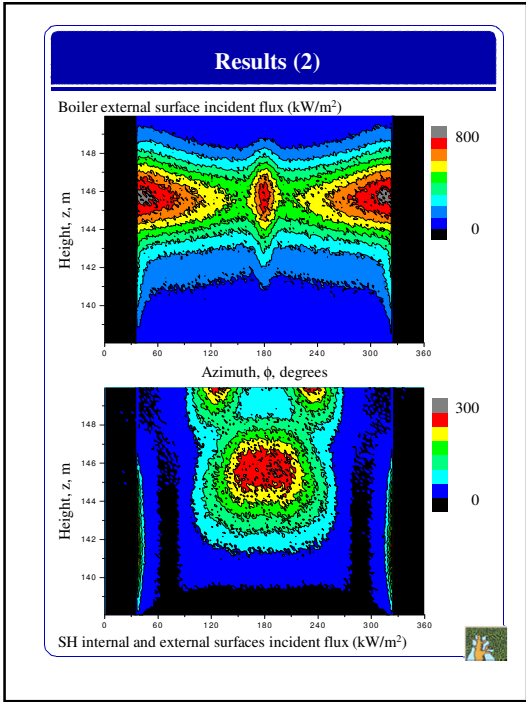
In our case:  $P=15\text{MPa}=2176\text{psi}$   
 $G=500\text{--}1100\text{ kg/m}^2\text{-s}\sim 0.3\text{--}0.8\text{ lb/ft}^2\text{-hr}$   
 $L/D=12/0.025=480$

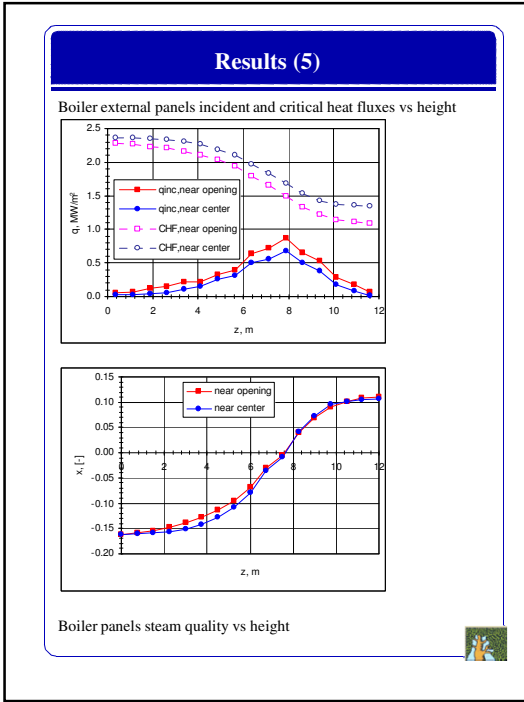
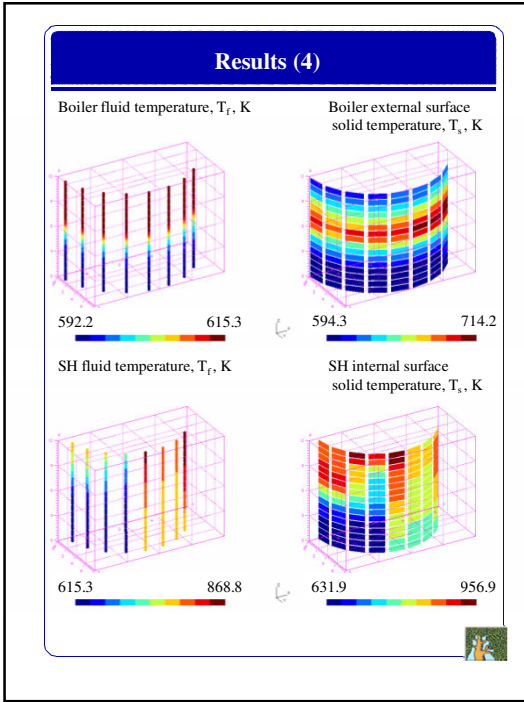


## Results (1)

|                          |                             |  |
|--------------------------|-----------------------------|--|
| <b>Geometry:</b>         | Receiver height             | 12m  |
|                          | Boiler diameter             | 16m  |
|                          | SH diameter                 | 14m  |
|                          | Opening angle (both)        | 72°  |
|                          | Pipes diam. (both)          | 3/4" schedule 80<br>(OD=26.7mm, ID=18.7mm) |
|                          | No. of pipes                | 1506 boiler<br>1318 SH                     |
| <b>Optics:</b>           | Date, time                  | Equinox, 12:00                             |
|                          | Insolation                  | 850W/m <sup>2</sup>                        |
|                          | Heliostat dimensions        | 4m x 4m                                    |
|                          | Heliostat reflectivity      | 0.9  |
|                          | No. of heliostats           | 3,652 for the SH<br>14,340 for the boiler  |
|                          | Tower height                | 138m                                       |
|                          | Total incident power        | 172.8MW                                    |
| <b>Other data:</b>       | Pressure                    | 15MPa                                      |
|                          | Wind speed                  | 0m/s                                       |
|                          | Boiler steam quality        | 10%  |
| <b>Integral results:</b> | Total flow rate             | 441.6kg/s                                  |
|                          | Total effective power       | 144.2MW                                    |
|                          | Efficiency                  | 83.5%                                      |
|                          | Receiver head loss          | 12.8kPa                                    |
|                          | Major losses                |  |
|                          | •Boiler external radiation  | 10.4MW                                     |
|                          | •Cavity re-radiation        | 5.9MW                                      |
|                          | •Boiler external convection | 2.1MW                                      |
|                          | •SH internal convection     | 2.1MW                                      |

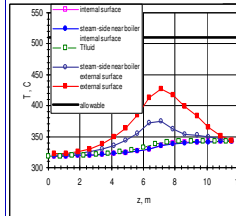




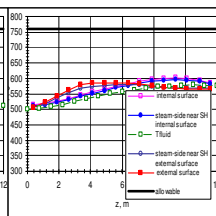
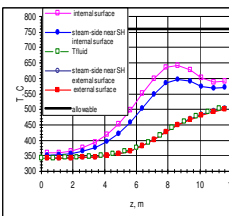
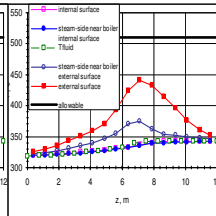


## Results (6)

Boiler temperatures  
near center vs height



Boiler temperatures  
near opening vs height



SH temperatures near  
center vs height

SH temperatures near  
opening vs height

