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Alternative Designs of a High Efficiency, North-Facing, Solid Particle Receiver

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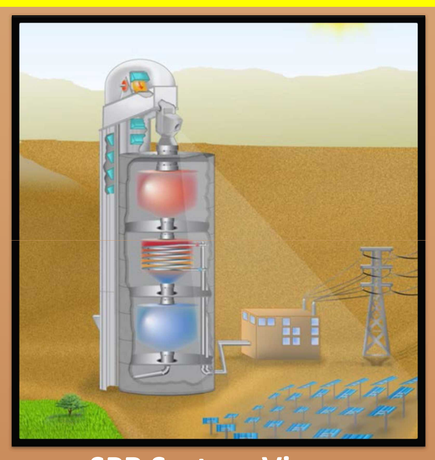
Introduction and Approach

Background

- Falling solid particle receivers (SPR) can enable increased working-fluid temperatures for central receiver power plants
  - Need thermal efficiency >90%
  - 700^{o} outlet temperature



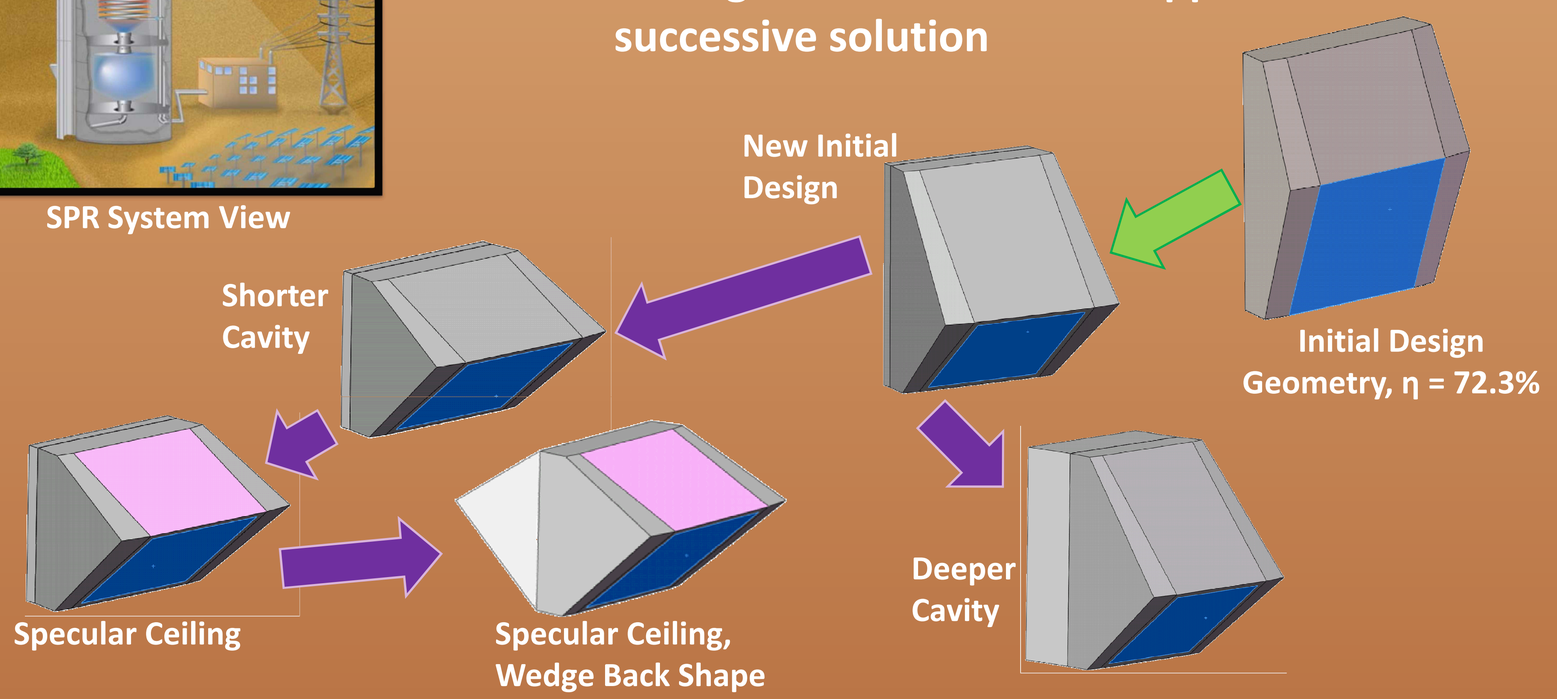
SPR System View

Problem Statement

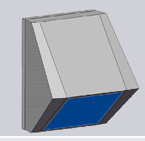
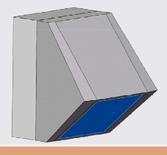
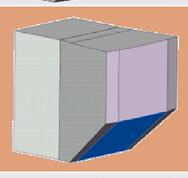
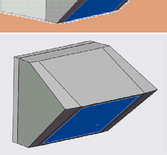
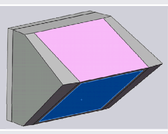
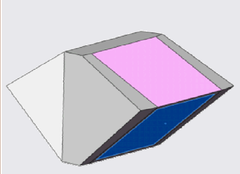
- What SPR designs can achieve the required >90% thermal efficiency ?
  - Analyze radiation and convection losses
  - Analyze particle losses

Approach

- CFD analysis performed on alternative SPR receiver designs to determine heat loss and particle loss
  - Design modifications are applied with each successive solution



Results – Thermal Efficiency, Heat Loss, Particles Temperature

Geometry	Design	Thermal Efficiency (%)	Radiative Loss (%)	Convective Loss (%)	Particle Outlet Temperature (^{o}C)	Notes
	Aperture=10.6 m, nod=50^{o}, h=20 m	68.8	7.45	22.8	651	High convective loss due to forced air out aperture (Solution = Increase cavity depth)
	Aperture=10.6 m, nod=50^{o}, h=20 m, *deep cavity = 5 m*	35.5*	8.48	22.8	965	*Low thermal efficiency due to 57.7% of particles being forced out aperture (Solution = Translate particle injection location)
	Aperture=10.6 m, nod=50^{o}, h=20 m, *deep cavity = 10 m, particle injection translated 2 m back, initial part. temp = 227^{o}C*	90.4	5.80	3.79	699	High thermal efficiency, No particle loss out of the aperture, Low convective loss, Initial particle temp lowered from 300^{o}C to obtain ~700^{o}C outlet temperature
	Aperture=10.6 m, nod=50^{o}, *h=12 m*	80.3	14.8	4.88	698	High radiative loss due to diffusely reflected radiation off slanted ceiling (Solution = Make ceiling specular)
	Aperture=10.6 m, nod=50^{o}, h=12 m, *specular ceiling*	85.8	8.67	4.81	741	High thermal efficiency (Problem = Specular ceiling very difficult to maintain at high temperatures)
	Aperture=10.6 m, nod=50^{o}, h=12 m, specular ceiling, *wedge back shape*	86.6	7.48	5.70	748	High thermal efficiency (Problem = Specular ceiling very difficult to maintain at high temperatures), Modified air currents behind particles

Conclusions

- Specular ceiling not realistic due to high temperature environment
- Cavity space behind particles is critical for convective losses, cavity shape can be modified to “tune” convective currents
- Particle injection location is critical for particle loss

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