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Sodium Receivers: State-of-the-Art and Future Developments

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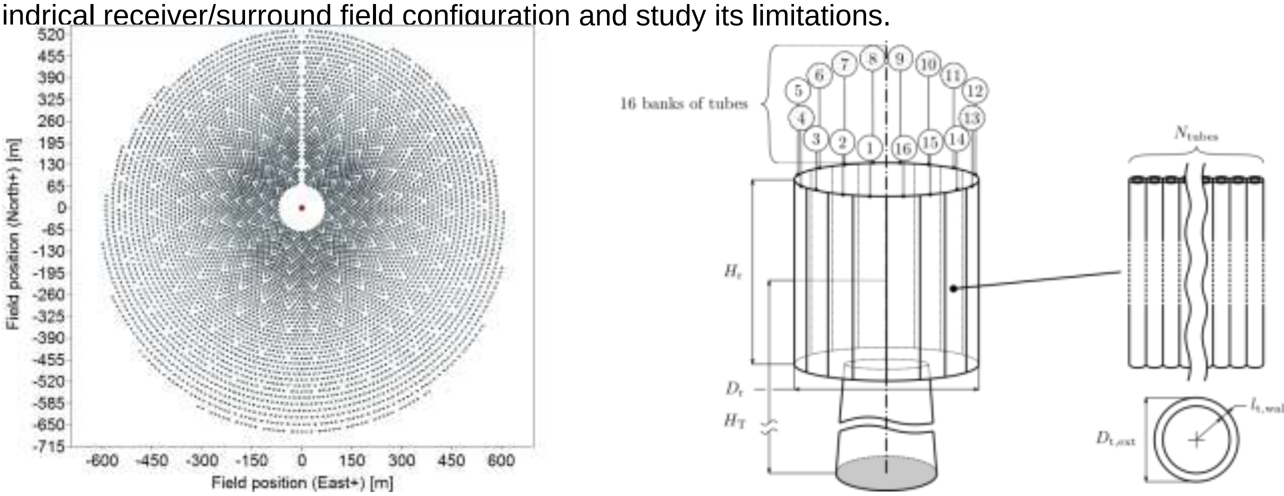
Liquid sodium is investigated as a heat carrier for the next generation of CSP systems within ASTRI. Liquid sodium has interesting heat transfer characteristics and has been shown to enable operations under high incident radiative flux when used as a heat carrier (HC) for solar receivers, with values of 1.8 MW/m^2 suggested in the literature as acceptable design limits [2]. Billboard, cavity and cylindrical type receivers have been suggested as candidate geometries for liquid sodium receivers [4, 1, 5]. In this work, we analyse the performance of the current state-of-the-art in receiver design: the cylindrical receiver/surround field configuration and study its limitations.



(a) (b)

Figure 1. ASTRI's reference heliostat field using a "gear staggered" layout and (b) Receiver geometrical model in this study.

To perform this analysis we couple a heliostat field optical simulation code [3] to an in-house cylindrical receiver model and run a large parametric stury on the receiver geometry, the optical error of the mirrors, the aiming strategy, the temperature of operation and the change to liquid sodium as heat carrier on the receiver efficiencies. The specific methodology used in this study enables the analysis of the combined influence and trade-off between thermal and optical constraints, including aiming strategy and peak flux on the receiver. Figure 2 illustrates the results for a molten salt receiver case.

The results show ~8.3% reduction in losses (~1.5% absol.lute efficiency improvement) associated with the use of liquid sodium over molten salt for temperatures and field optical error consistent with commercial systems.

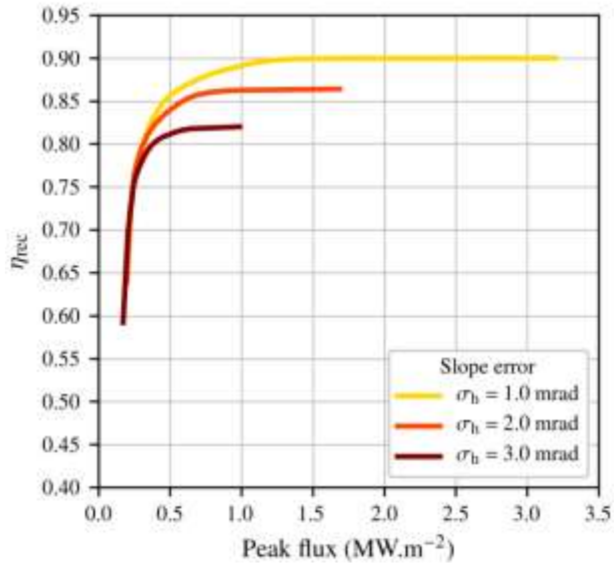


Figure 2: Pareto fronts highlighting the design trade-off between peak flux and receiver efficiency for cylindrical molten salts receivers on the ASTRI field system.

Going to higher temperatures, we show that the optical quality of the helisotat field becomes very important for the overall system efficiency and that spillage limits the performance of cylindrical receiver systems. Our study reveals that cylindrical receivers seem unable to meet the efficiency goals set by ASTRI (>91%) and the Sunshot GEN3 (>90%) programs if the overall receiver efficiency is considered, including both optical and thermal considerations.

Table 1: Maximum receiver efficiencies considering the change in heat-carrier, flux limitations and heliostat optical error. Cells filled with "-" indicate that no improvement in receiver efficiency was obtained by increasing the flux limit.

		Receiver efficiency								
HC		Molten salt			Na (310°C -> 585°C)			Na (500°C -> 720°C)		
Flux limit (MW/m^2)		≤1	≤1.8	≤2.5	≤1	≤1.8	≤2.5	≤1	≤1.8	≤2.5
Optical error	1 mrad	0.887	0.900	-	0.897	0.911	-	0.852	0.878	0.879
	2 mrad	0.863	0.864	-	0.873	0.875	-	0.821	0.826	0.829
	3 mrad	0.820	-	-	0.830	-	-	0.761	0.764	-

Finally we conclude the study on some of the current developments in receiver geometry design aiming at overcoming the limitations imposed by the cylindrical receiver concept.

References

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