DISCLAIMER

51908
Sandlin-SNL

Research Performance Progress Report (RPPR-1*)*

SECTION I: COVER PAGE

a. Federal Agency	Department of Energy	
b. Award Number	51908	
c. Project Title	Characterizing falling particle curtain receivers at commercially relevant scales	
d. Recipient Organization	Sandia National Laboratories	
e. Project Period[1]	Start: 6/1/24	End: 8/30/25
f. Budget Period	Start: 6/1/24	End: 8/30/25
g. Reporting Period	Start: 6/1/24	End: 12/31/24
h. Report Term or Frequency	Bi-annually	
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[signature] 1/2/2025

Signature of Certifying Official Date

By signing this report, I certify to the best of my knowledge and belief that the report is true, complete, and accurate. I am aware that any false, fictitious, or fraudulent information, misrepresentations, half-truths, or the omission of any material fact, may subject me to criminal, civil or administrative penalties for fraud, false statements, false claims or otherwise. (U.S. Code Title 18, Section 1001, Section 287 and Title 31, Sections 3729-3730). I further

[1] If you have received No Cost Time Extensions (NCTE), please add a note below the table indicating the length of each one and which budget periods were affected.

understand and agree that the information contained in this report are material to Federal agency's funding decisions and I have any ongoing responsibility to promptly update the report within the time frames stated in the terms and conditions of the above referenced Award, to ensure that my responses remain accurate and complete.

SECTION II: EXECUTIVE SUMMARY

Major Goals and Objectives

Sandia will construct a cold flow receiver test platform in order to characterize falling particle curtain receivers at commercially relevant scales. While Sandia has extensive experience in R&D of falling particle curtain receivers, most have been at pilot scale and smaller - on the order of 1 MW_{th} with characteristic dimensions of nominally 1-2 m to adequately collect solar energy from the heliostat field at the National Solar Thermal Test Facility (NSTTF). However, scaling up receivers to commercially relevant scales (25 MW_{th} and above) will require a thorough understanding of particle curtain dynamics at larger scales, especially longer drop heights, for design certainty.

The goal of this project will be to construct a cold falling particle curtain test rig capable of simulating particle characteristics that are expected in a commercial scale CSP plant, namely the drop height, curtain thickness, and particle mass flow rate (normalized by length of curtain). This will enable data collection on curtain opacity and spread, both of which are correlated to receiver efficiency and reliable construction, for commercially relevant scales. It will also permit validation of numerical models that will enable detailed receiver characterization and design past currently validated scales.

Technical Achievements

The test platform structural steel has been designed and analyzed for static and seismic loads. The structural steel sections and inlet hopper have been fabricated. The image capturing system has been designed. Initial modeling efforts are underway.

Impact:

We will develop a test platform capable of experimental investigations into falling particle curtain receivers at commercially relevant drop heights and linearized mass flow rates. We will use this facility to validate numerical models of said falling particle receivers in order to produce tools that can be used to design next-generation commercial scale CSP facilities. The test platform will target receiver flow rates, receiver heights comparable with commercial receivers; and target innovative “catch and release” feeders that can increase curtain opacity.

Project Schedule Status:

The project is behind schedule by approximately 3 months. This is mostly due to staff turnover, which has occurred at all technical levels (engineering, technician, interns). It is anticipated that the project can re-gain some ground in the testing phase and end within the scheduled window. However, we are anticipating a lot of competition for testing time and space with planned testing occurring on the current test tower where this project is being installed.

Project Budget Status:

The project has spent approximately half of the planned budget. However, it was always anticipated that project spending would be heavily front-loaded due to purchasing and fabrication costs. There are no concerns with the budget at this time.

Key Personnel Changes:

Due to other commitments, modeling work has been taken over from Brantley Mills by Aaron Spieles. Aaron is recent hire (<1 year) within the Sandia CSP group. He has extensive DEM modeling experience from his graduate work at the University of Dayton where he also performed lab-scale interrupted flow particle curtain experiments.

Scope Issues:

Nothing to report.

SECTION III: TASKS AND MILESTONE PROGRESS

The project is arranged into three tasks that are roughly sequential: commercial scale falling particle receiver (FPR) design and build, testing, and modeling.

Task 1.0 – FPR design and build:

The main structural elements for the FPR test platform have been designed and fabricated. The main structure consists of 3 tubular steel "cubes" which, when stacked, form the majority of the height of the structure, and a dedicated inlet hopper module, complete with inlet hopper, particle curtain generating valve (PCGV), and load cells. There is a smaller support structure in front of the curtain location which will support cameras, lights, and other imaging hardware.

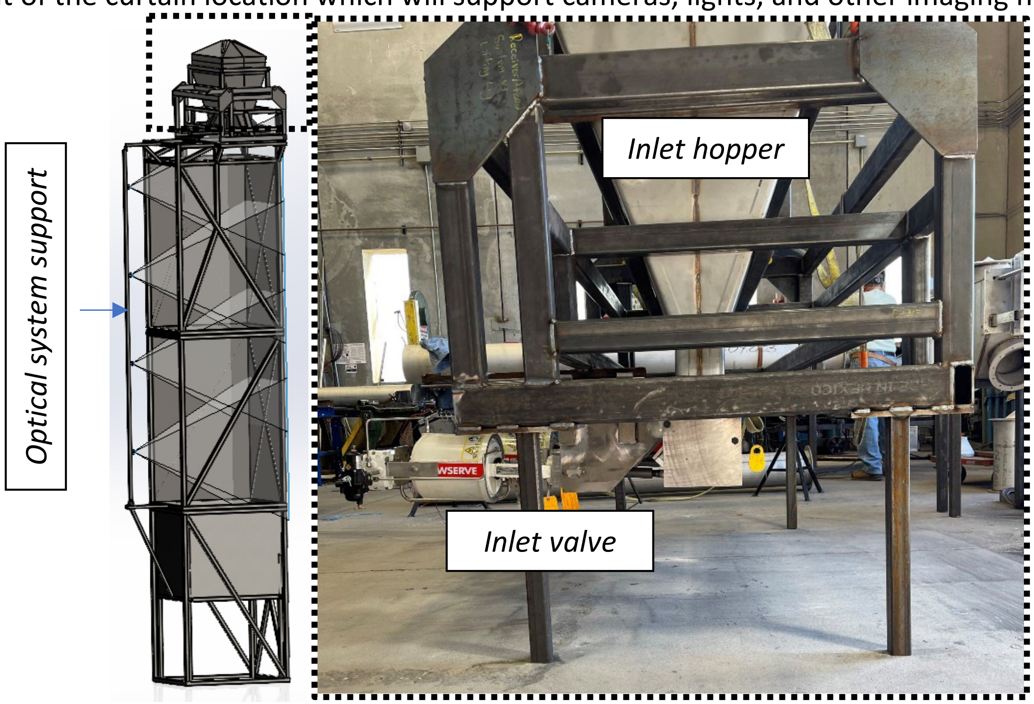

Figure 1 - (left) CAD model of the FPR tower structure. (right) completed inlet hopper module, showing support steel, inlet hopper, and inlet valve.

The bulk of the structural steel has been fabricated and is on-site. The components will be installed early next quarter in the current test tower (i.e., not the under-construction G3P3 tower). It will be installed on the Lucker lift module in order to use the existing bucket elevator for continuous particle circulation at lower flow rates.

Another early task 1 milestone was to fabricate one of the STAiR modules to be tested. Sandia has several STAiRs (~4-6 individual pieces) fabricated for a previous project that we will re-use for this project. While they need modification – cut to correct width, modify back and sides to handles high flow rates, and design the attachment system for them – they are of the "hybrid" design that has previously been shown to be suitable for generating particle curtains.

Cameras have been specified and purchased. As it is unlikely that this project will be able to incorporate PIV analysis of the particle curtain, the cameras have generally traded high frame rates for high resolution, enabling higher accuracy in analyzing single images and offering better cropping capability to reduce the size of the final images.

Task 2.0 – FPR test campaign:

As the test campaign is gated by the installation of the test hardware, this task has not yet begun in earnest. We are planning to perform similar measurements as have been demonstrated in the past for curtain opacity and curtain width.

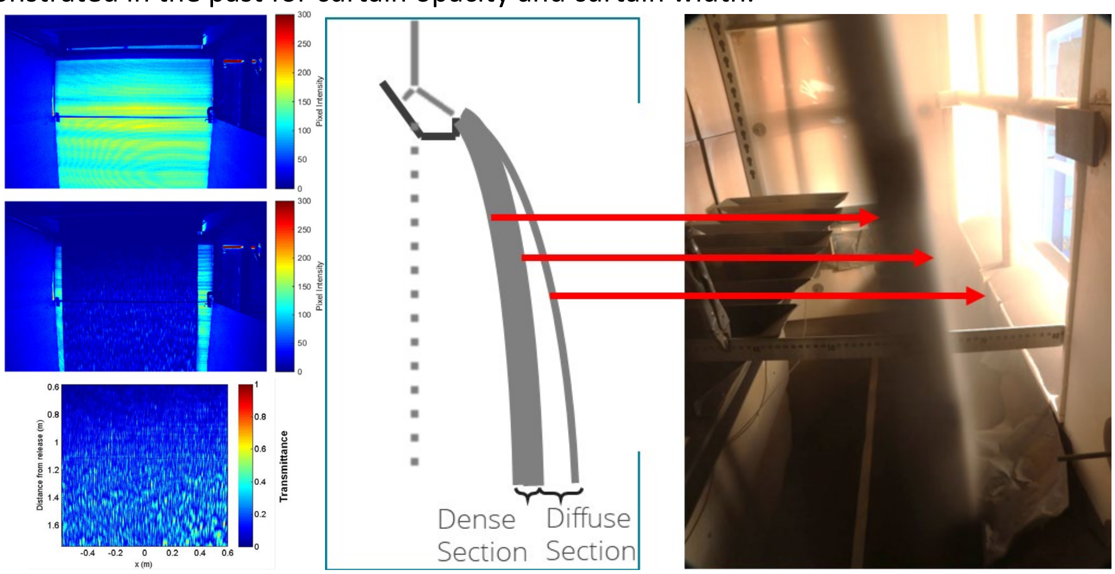

Figure 2 - examples of measuring (left) curtain opacity and (right) curtain width.

Task 3.0 – FPR modeling:

The FPR modeling effort has been taken over by a new engineer in the CSP group, Aaron Spieles. He has experience in both DEM modeling and lab-scale interrupted flow FPR experimentation from the University of Dayton. Thus, while he is very familiar with the overall project methods and objectives, the early part of the modeling effort is devoted to helping him get up to speed with Sandia modeling tools, such as Sierra (CFD) and LAMMPS (DEM). We have constructed a plain falling particle curtain model and a simple interrupted flow curtain model (instead of a true STAiR, the particles impact an inclined plain) in order to facilitate this development activity. The models are constructed using a dense-discrete phase model (DDPM). Using this approach, macroscale "particles" which represent approximately 2500 real particles are inserted into the domain to simulate overall particle flow. These particles interact with the surrounding fluid via drag, and particle collisions are currently handled by a very simple coefficient of restitution model, rather than the more complicated models typically employed by true discrete element method (DEM) model. While this is anticipated to be satisfactory for the plain falling particle curtain – where particle interactions should not play a major role in curtain behavior far from the PCGV – it is unknown if this approach will work for the interrupted flow curtains, which explicitly depend on particle collisions. A DEM model will be constructed later in the project to assess the validity of the DDPM model for interrupted flow curtains.

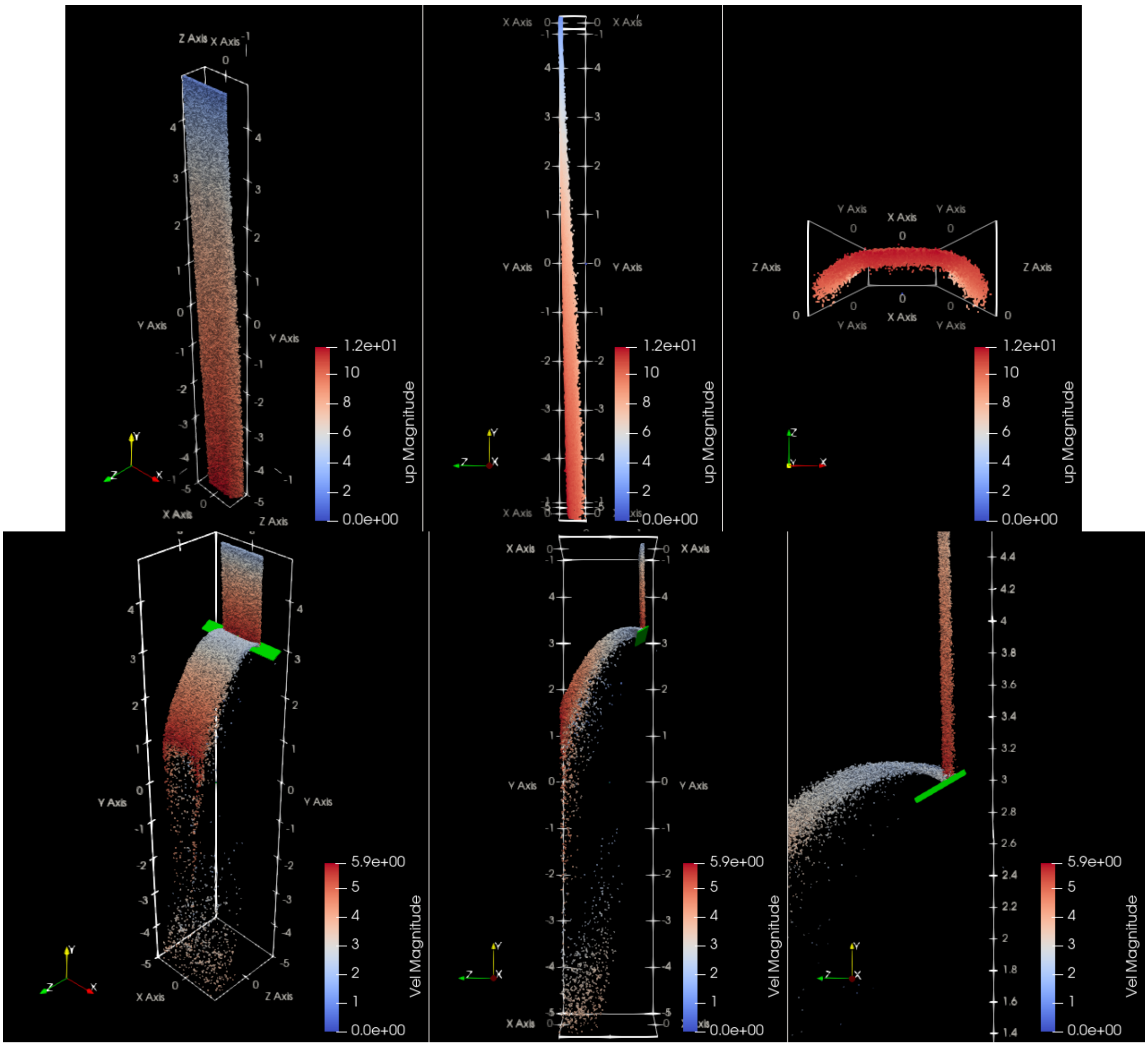

Figure 3 - DDPM model of a freefall curtain (top) and an interrupted flow curtain (bottom).