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Flexible Hose Interconnect Testing for Parabolic Troughs with Nitrate Salt

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I. Project Overview

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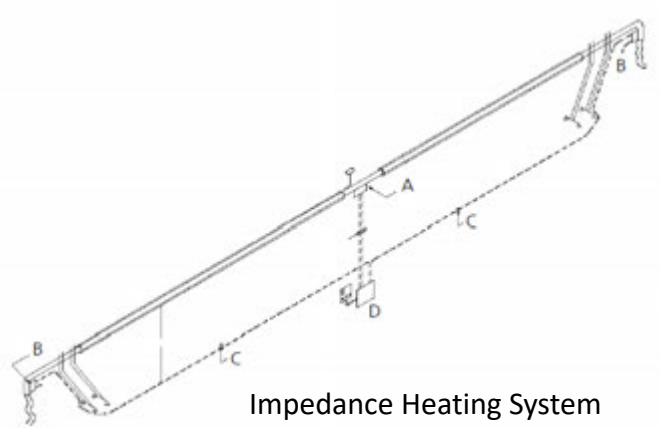
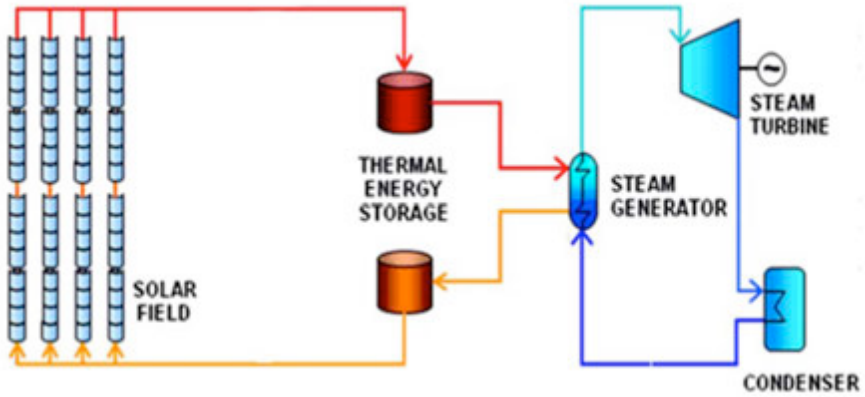
SMART Molten Salt Trough Project: **S**implified **M**elting **A**nd **R**otation-joint **T**echnology for Molten Salt Troughs

Funded by U.S. Department of Energy, Solar Dynamics, and others
Project DE-EE0008140



Impedance Heating System

Collector Molten-Salt Interconnection



Design, Performance, and Cost Models

Why Molten Salt Troughs?

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- Same operational benefits as Molten Salt Towers
  - Higher temperature → higher Rankine cycle efficiency
  - Heat transfer fluid and storage medium become one and the same (eliminates HX)
  - Higher energy density → smaller storage volume → lower cost storage
  - Flexible dispatch, de-coupled from energy collection
- Lower profile than Molten Salt Towers (easier siting and permitting)
  - Less visual impact
  - No bird issues or perception thereof
- Challenges:
  - High freeze temperature & high cost of freeze protection
  - Lack of reliable interconnect solutions
  - Limitation of publicly available modeling tools

Presentation covers these topics

So What's New?

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- The prospect of using Molten Salt as an HTF medium is not a new concept
  - Many studies have been made
  - Many tests have been conducted, even full collector loops

- Despite the work that has been done, little information exists publicly, particularly physical tests and demonstrations
  - A primary goal of this project is to publicly disseminate information for the benefit of the industry
  - This presentation covers a couple recent success stories
  - Any failures in the future will also be shared for the benefit of the industry

II. Interconnect Benchmarking for Parabolic Troughs with Molten Salt

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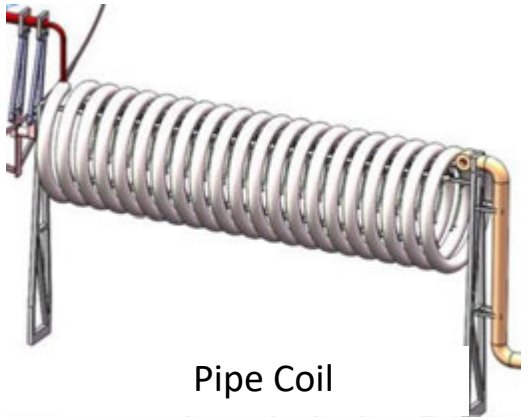
- Ball joints and rotation joints
  - Most commonly used in oil HTF plants
  - Poor lab test history with MS (Abengoa and others)
  - New packing and sealing materials may present opportunity

Ball Joint

- Flexible hoses ("flex hoses")
  - Commonly used in oil HTF plants
  - Prior lab tests with MS have had limited but promising results (Abengoa and others)
  - Solar Dynamics has conducted further lab testing

Flexible Hose

- Pipe coil or "Flexible Rotary Pipe Coupler"
  - Demonstrated in Lab
  - No known commercial deployments
  - Consumes more real estate
  - System analysis indicates higher pumping parasitics, greater thermal losses → higher LCOE



Pipe Coil

Prior Lab Testing (Abengoa & University of Wisconsin-Madison)

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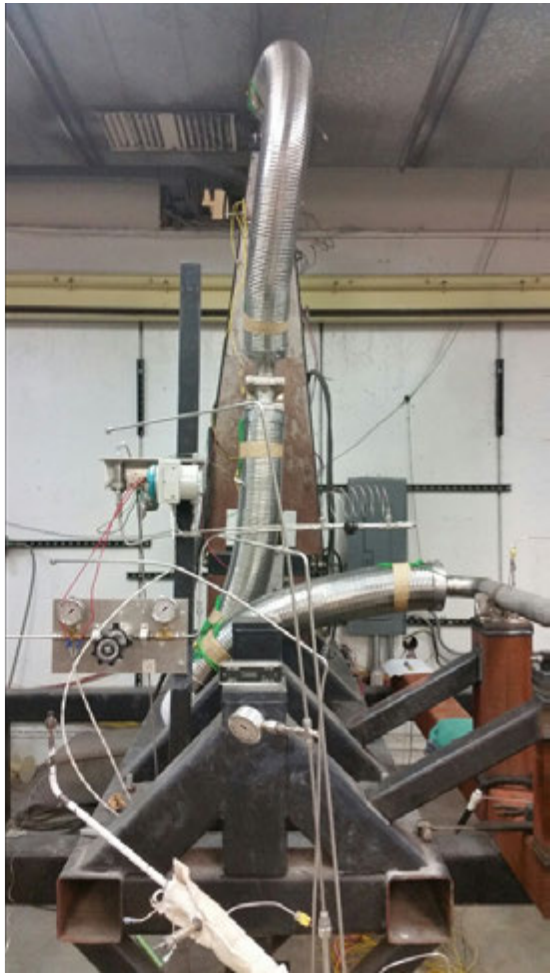
- Most Successful Test Result:
  - Salt: 60% $NaNO_3$ 40% KNO_3
  - Temperature
    - 500°C
  - Pressure
    - 25 bar (363 psi)
  - 6470 cycles completed before shutting down test without flex hose failure – represents approximately 18 years of operating life



Key Findings from Prior Flex Hose Testing

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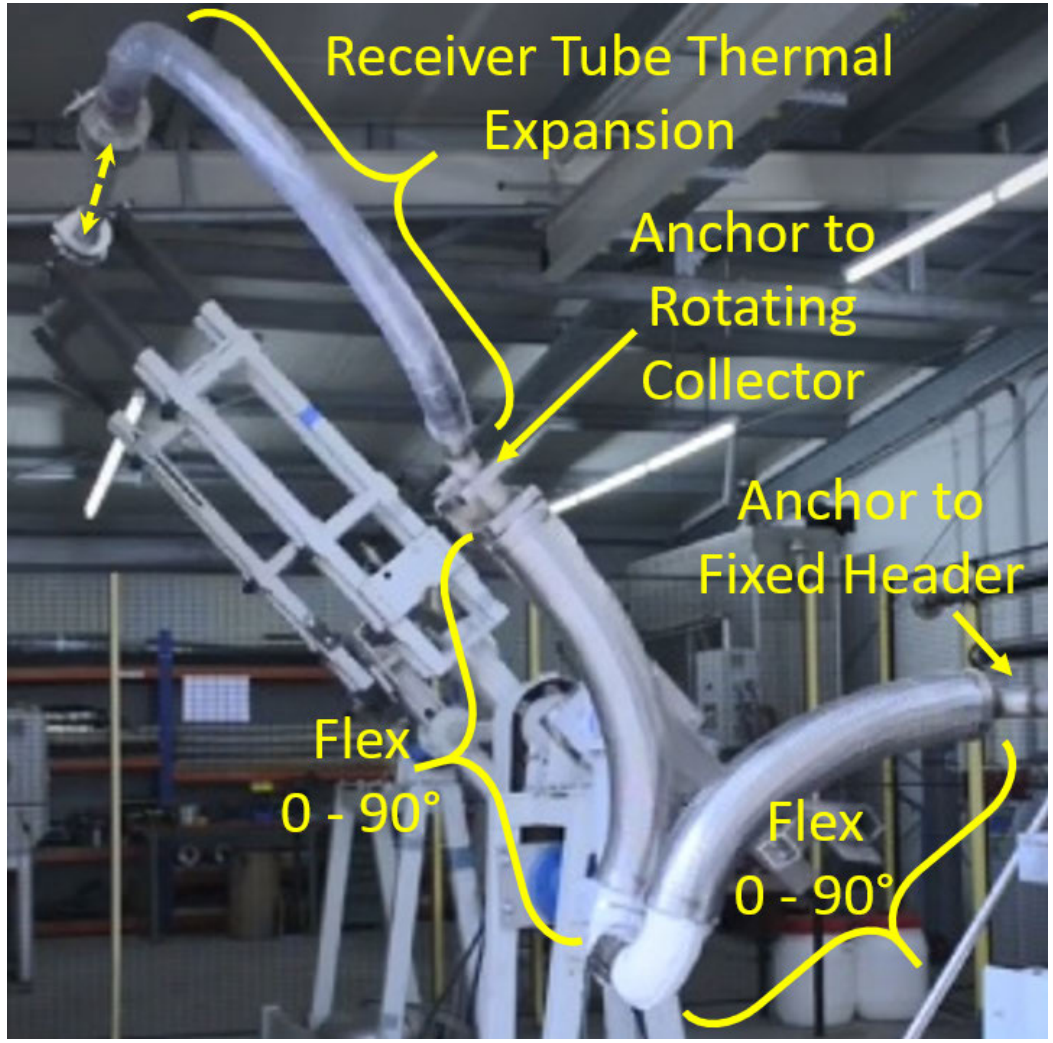
- A design life exceeding 10 years seems achievable
- Limiting the degrees of bending of each flex hose extends the life
- Effects of fatigue can be reduced by limiting the motion of each flex hose to bend in only one direction
- Senior Flexonics has designed a triple hose configuration that requires no rotational joint and limits the degree of bending of each hose to less than 90°



Senior Flexonics TripleFlex Design

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III. Flex Hose Mechanical Testing by Solar Dynamics

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- Can the design withstand the combination of temperature, pressure, and mechanical cycling needed for commercial service?
- Goal: complete accelerated cycle testing to demonstrate 10 years of mechanical life at process condition extremities
- Two prototypes were tested with molten salt at temperatures and pressures representing loop inlet and loop outlet conditions.

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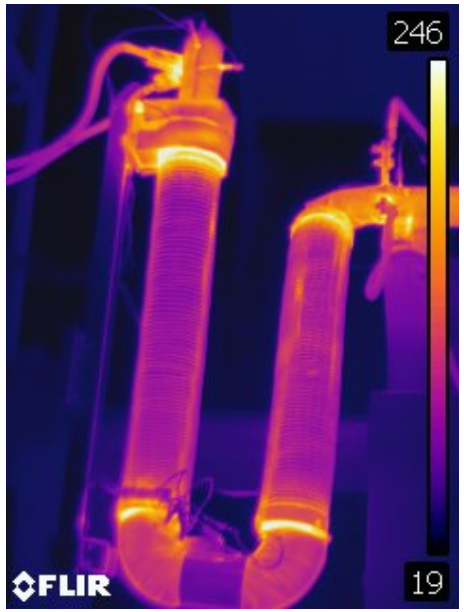
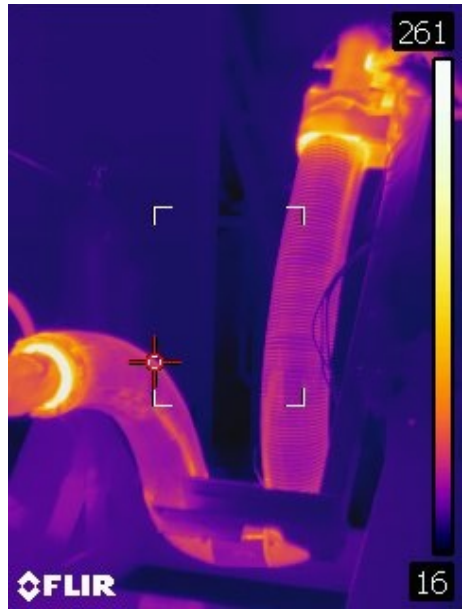
New hose upon shipment

Initial Salt Filling



Impedance heating to 550 °C



Cycling under temp. & press.

Video of Interconnect Testing

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Solar Dynamics Testing with University of Wisconsin-Madison

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- Prototypes were cycle tested with molten salt
- Goal: complete accelerated cycle testing to demonstrate 10 years of mechanical life at process condition extremities

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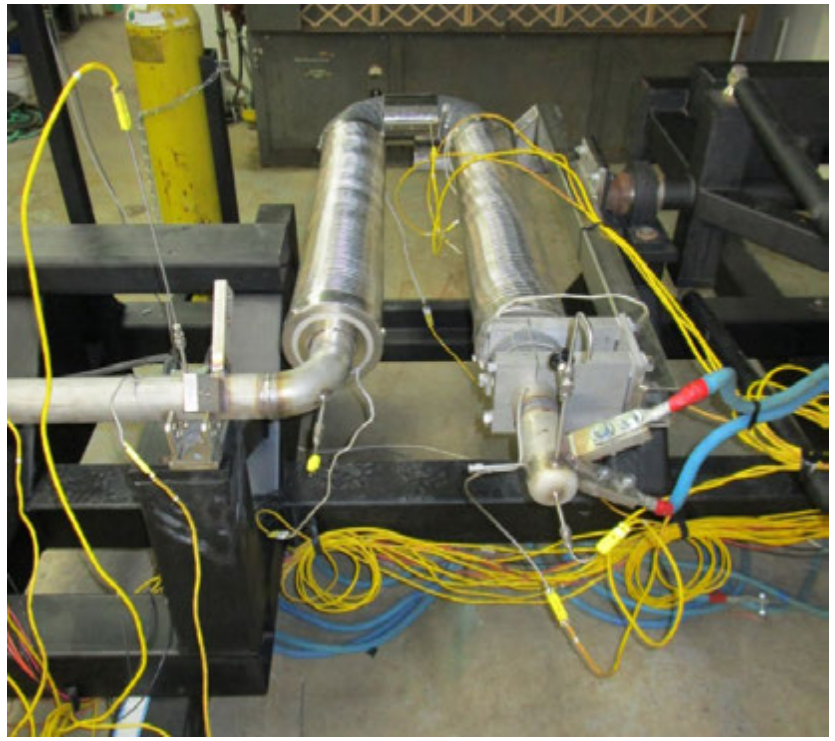
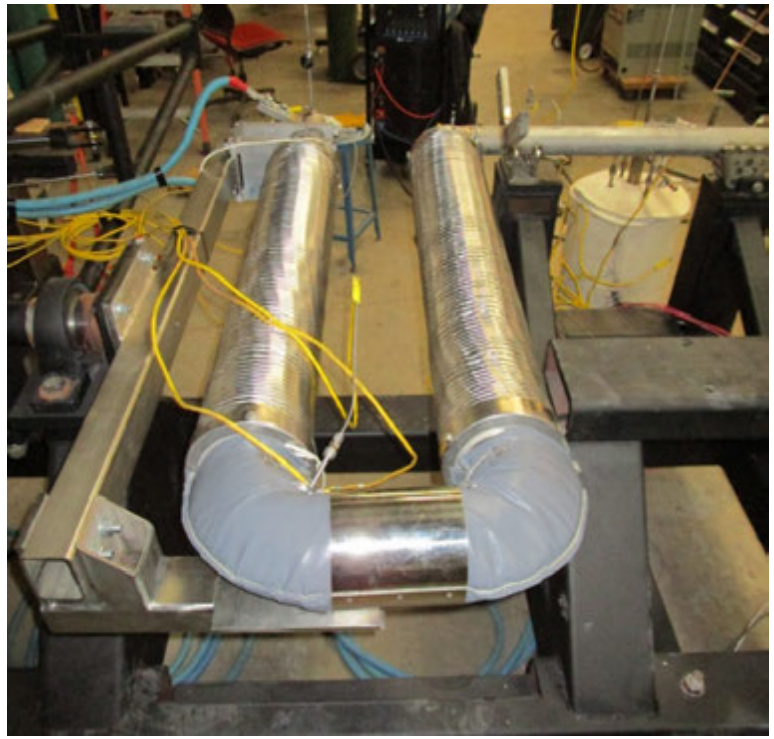
- Test Results:
  - Loop Outlet Conditions
    - 550 °C, 14.0 bar
    - 11,440 cycles completed, representing 30+ years without any failure
  - Loop Inlet Conditions
    - 305 °C, 31.5 bar
    - 10,200 cycles completed when leak occurred, representing 28+ years





Limitations of Test Results

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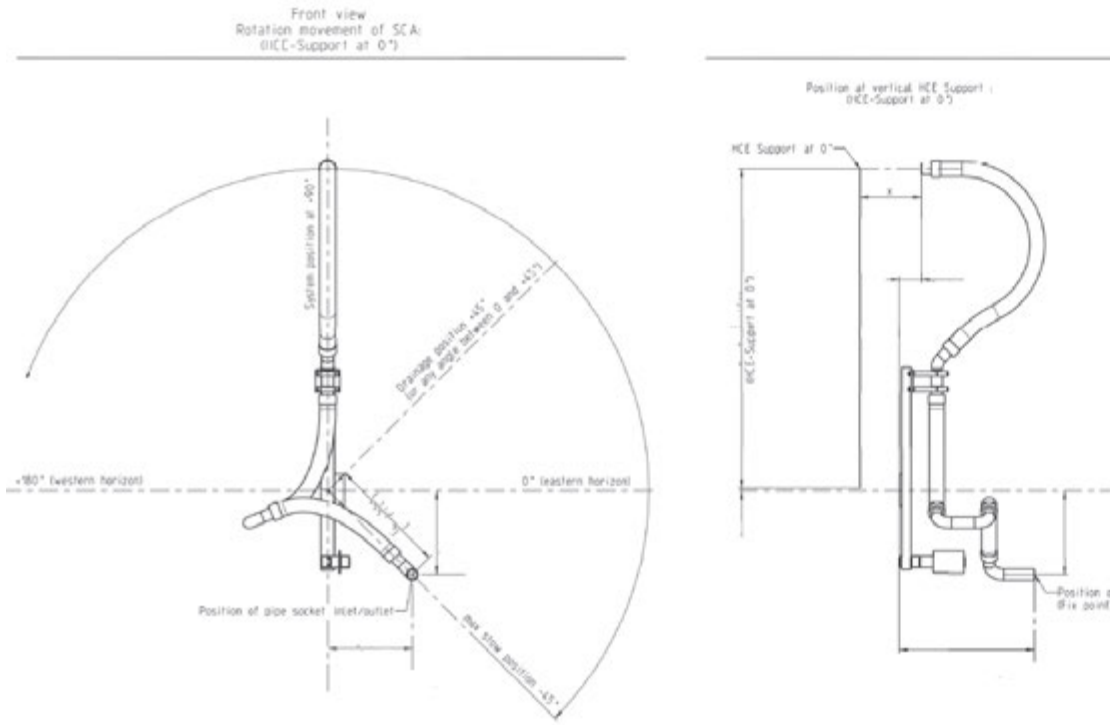
- Mechanical fatigue testing only
- Does not account for factors including:
  - Daily temperature and pressure cycling
  - Oxidation / stress-corrosion cracking
  - Ambient weather conditions
  - 30 years of actual life in the field

- Nonetheless, the test results are promising, presenting a compelling interconnect solution for parabolic troughs with molten salt



Next Steps in Testing

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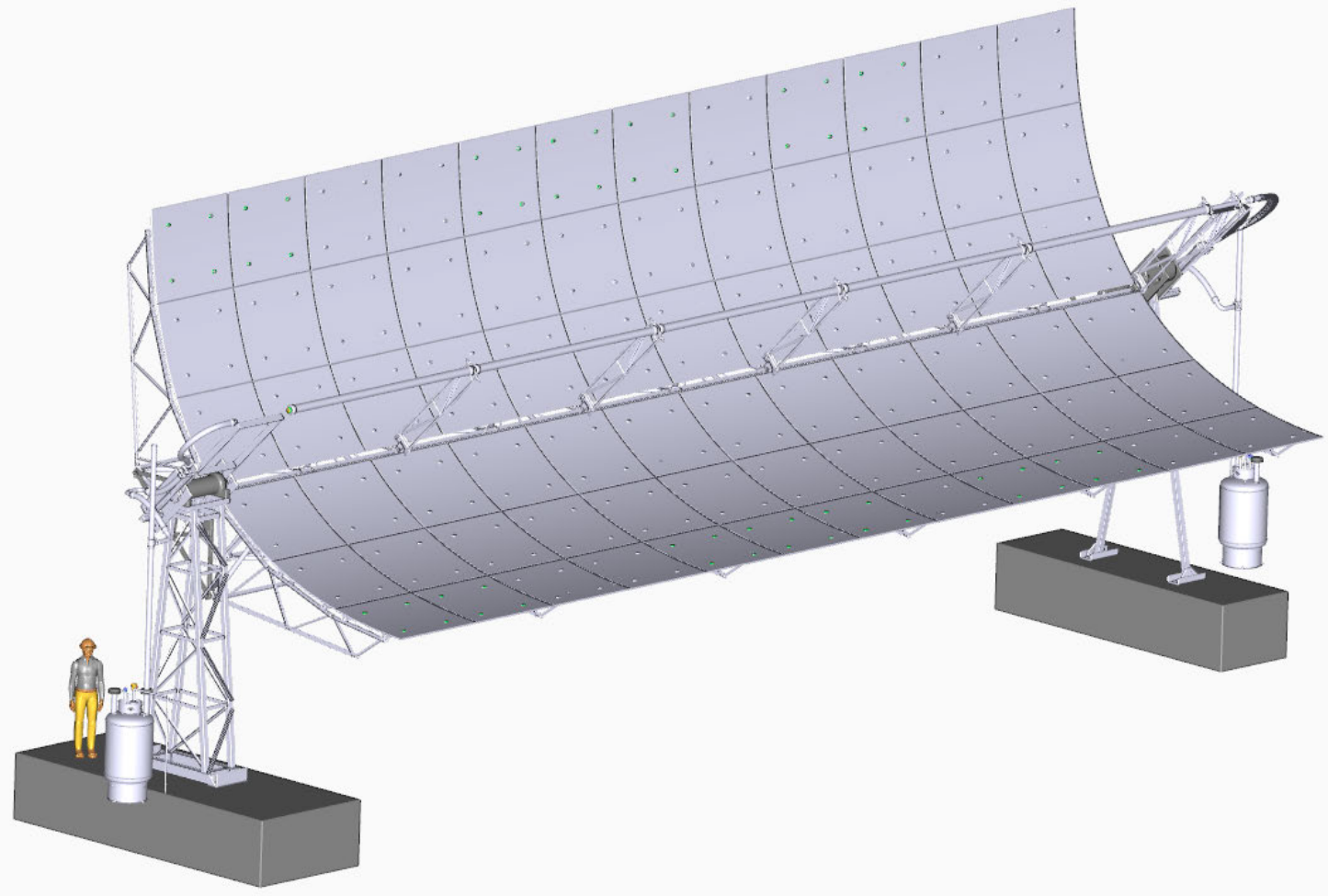
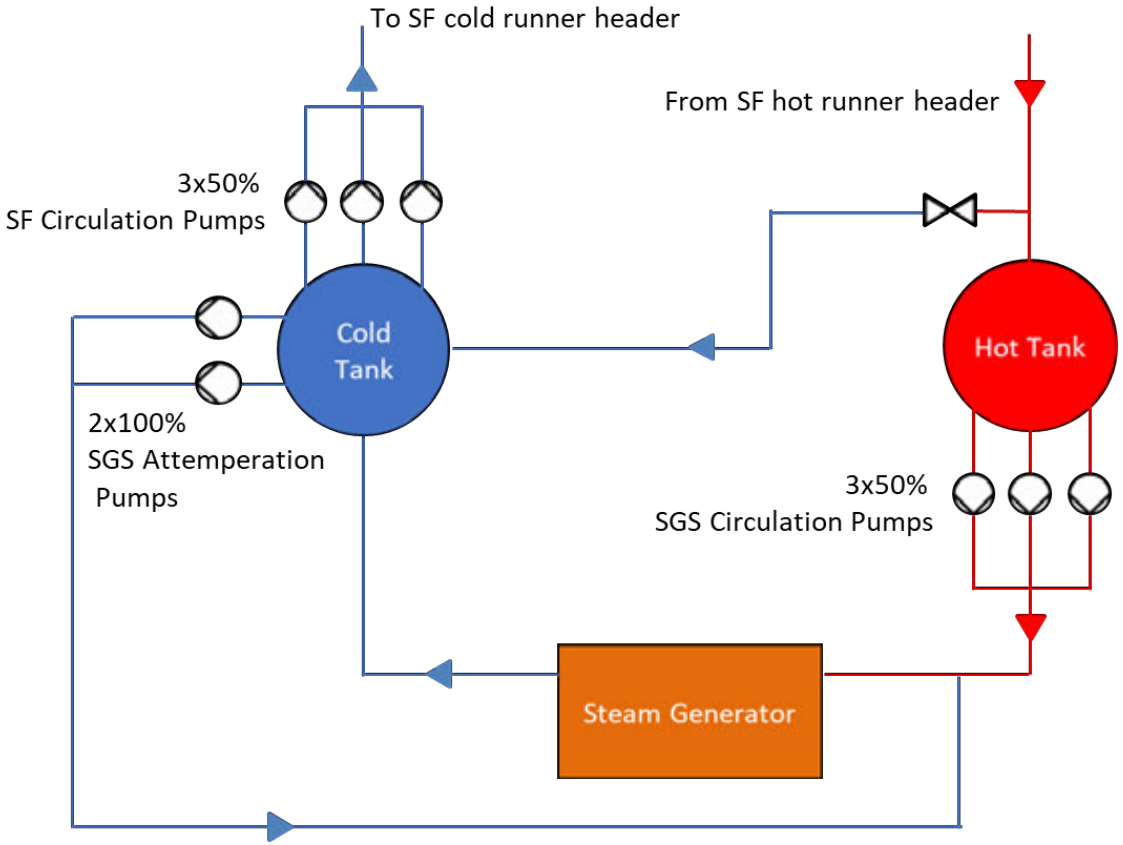
- Single Module Test Site
  - Being constructed in late 2019
  - Freeze protection testing with impedance heating
  - Freeze / thaw component testing
  - Using concentrated solar to augment freeze protection and freeze recovery
  - Uses Solar Dynamics 8.2 m aperture x 20 m length SunBeam™ collector



IV. System Advisor Model ("SAM") Updates

- NREL modified the Physical Trough Model in SAM
  - Publicly available with SAM release v2018.11.11
- Peaker configuration option (distinct collection and generation flow loops)
  - Solar field piping design now saved in user accessible outputs
    - Allows sizing of heat trace and integration to overall piping cost model
  - Custom solar field pipe diameter option
    - Allows user to optimize each pipe section
  - User defined interconnects
    - Allows simulation with flex hose, Brayton Coil, and future designs



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Thank you for your attention!

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