SunShot U.S. Department of Energy

CSP Program Summit 2016

BraytonEnergy

FLEXIBLE ROTARY PIPE COUPLER

"The Salt Coupler"

Contract: DE-SC0011965

Project Period: 2016-09-01 - 2017-08-31

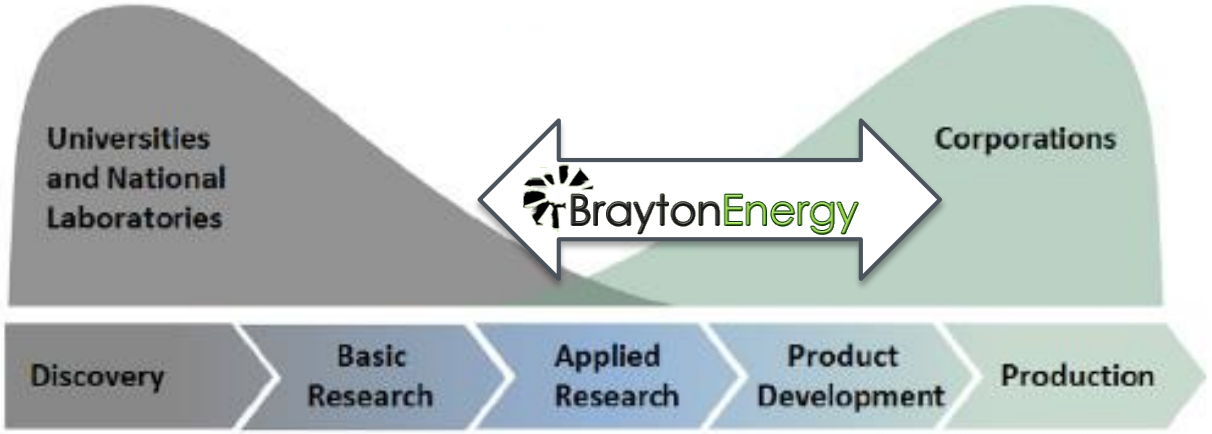
Funding: Phase II $1,491,530

William Caruso, Principal Investigator

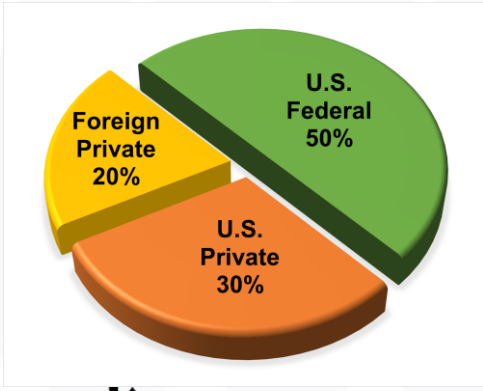
Intro to Brayton Energy, LLC

"… to design and build hardware solutions for sustainable, efficient energy systems through applied research, revolutionary innovation, sound engineering, and dedicated partnerships with our clients."

- Advanced Energy R&D firm
- Located in Hampton, NH
  - 50 miles north of Boston

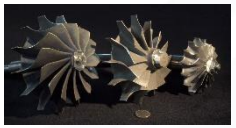


SRI International

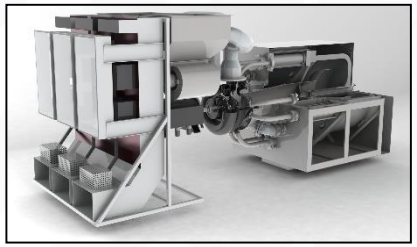


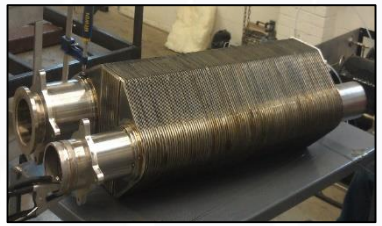
Intro to Brayton Energy, LLC

- Turbomachinery solutions
  - Power systems
  - Biomass
  - UAVs
  - Transportation
- CSP components
- High-temperature compact heat exchangers
- Advanced system modeling and analysis
- Energy storage solutions (thermal, CAES)





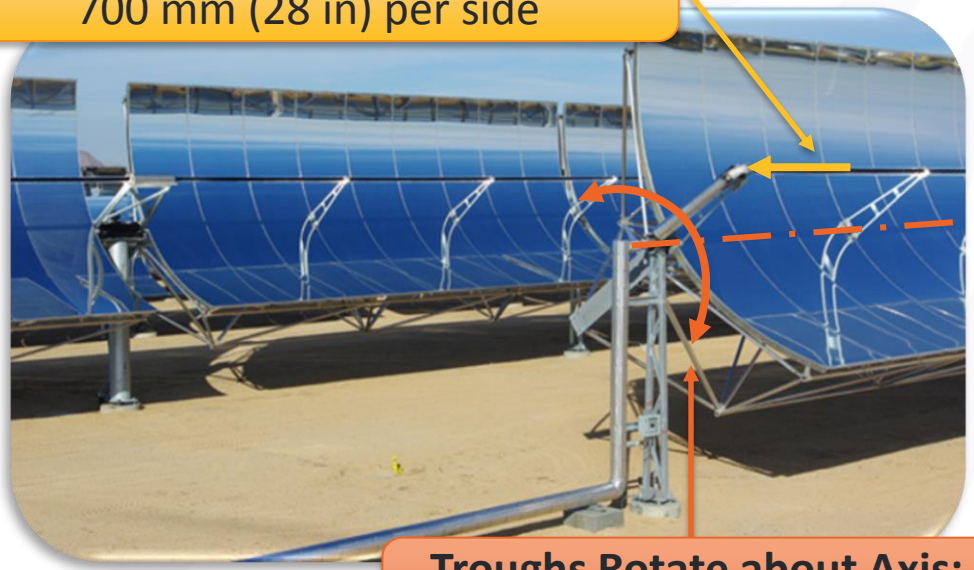




The Challenge

- Develop a cost competitive flexible pipe coupling suitable for the full service life of a trough solar receiver using molten salt as a heat transfer fluid at 500°C or greater.

Receiver Tube Thermal Expansion:
700 mm (28 in) per side

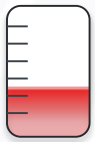


Troughs Rotate about Axis:
230°

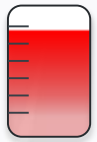
Support Potential Industry Shift:

Hot Oil to Hot Salt

400°C



550°C



***Direct* Salt Systems:**

Advantages

- Decreased thermal storage costs
- Increased power block efficiency

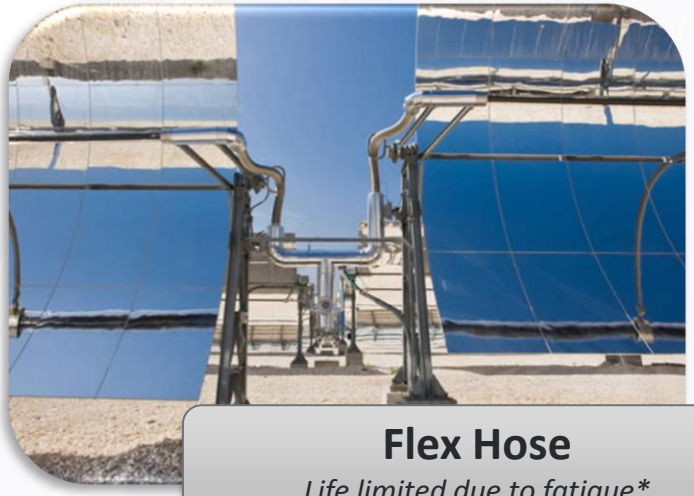
Challenges

- Reliability
  - Leaking
  - Material compatibility (corrosion)
  - Freezing

Existing Technology

- **Thermal Oil System** - several mature options for rotary coupling
  - Rotary Coupling - Ball Joints & Face Seals
  - Corrugated flex hoses
- **Molten Salt**
  - Oil options (above) have reliability issues

Rotary Coupling
*Excessive leakage**



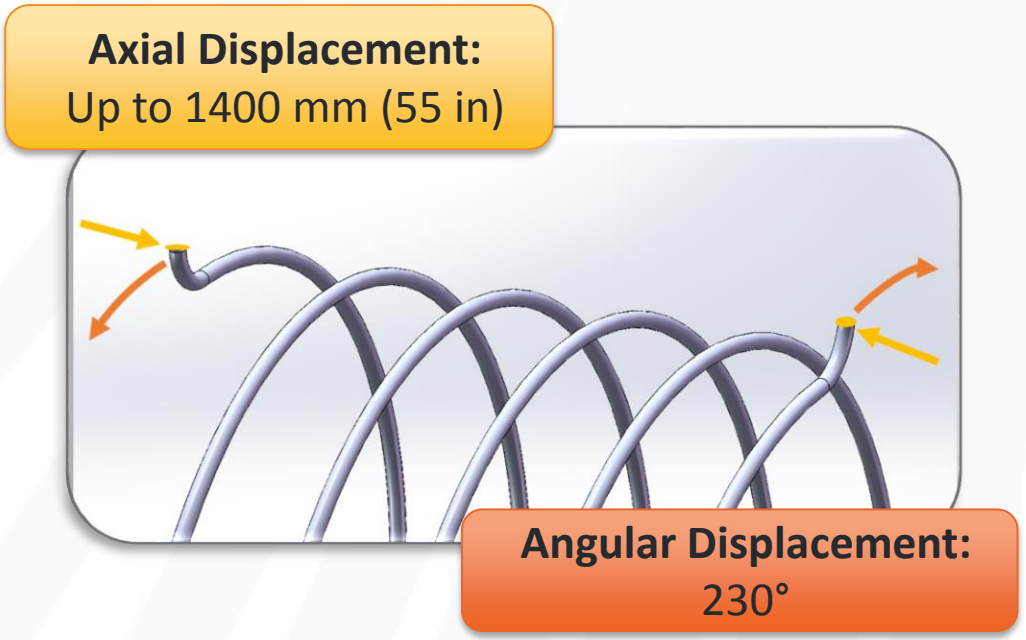
Flex Hose
*Life limited due to fatigue**

*According to D. Grogan, Abengoa, *Development of Molten Salt for Parabolic CSP Troughs,* SBIR DE-FC36-08GO18038

Brayton's Solution - *The Salt Coupler*

Helical Coil Pipe Coupling System

- Optimal helical pipe configuration for strain tolerance
- Stabilization and support system (*not shown)*
- Insulated for low heat loss
- Integral freeze recovery system
- Certification to ASME standards B31.1 & B31.3



Brayton's Solution - Value and Challenges

Advantages		Challenges	
Code	Meets piping code ASME B31.1	**Draining**	May require forced draining (purging)
Robust	Tolerance to high temperatures and pressures	**Shadow**	Due to size, higher solar blockage (shadowing)
Integration	Adopts proven freeze prevention & recovery system	**Heat Loss**	Potentially higher heat loss
Life	30+ year life matches plant piping	**Pumping**	Potentially higher pump parasitic (pressure drop)
Leak-free	Contiguous, certifiable welded construction	**Support**	May require substantial support structure (cost)
Low Maintenance	Adopts plant piping O&M costs		
Standard	Standardized components		

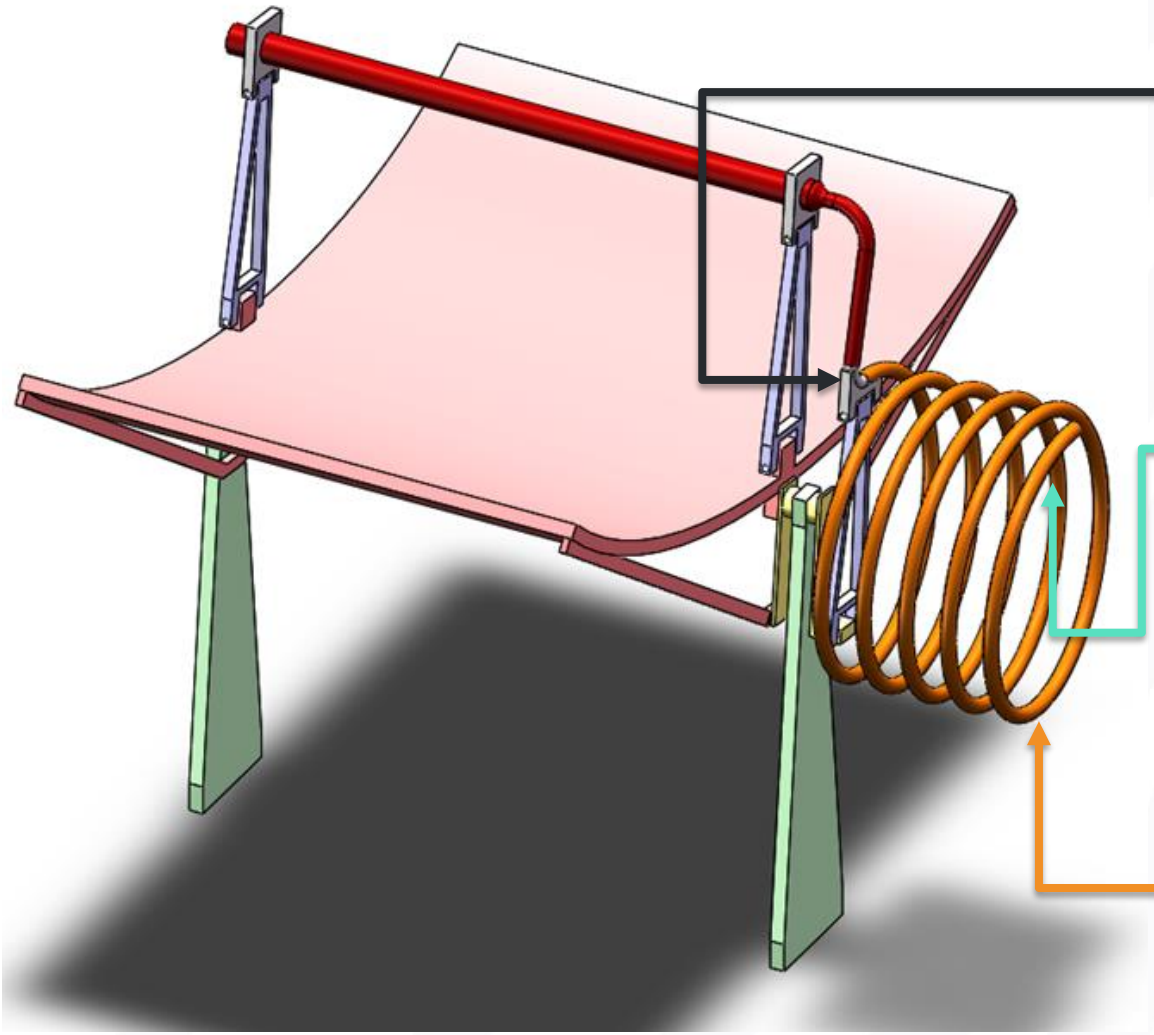
Table of Results

Performance Metric	Product Specification
Material	Austenitic Stainless Steel (300 series)
Max Rated Temperature	565°C
Pressure Drop	<33 kPa (5 psi) average
Pumping Power	<0.2 kW (¼ hp) average
Flow Rate	11 kg/s (90 gal/min)
Pressure	45 barg (650 psig)
Cycles to Failure	>11,000 *(1/day, 30 years)*
Creep Life	no practical limit
Cost	<$10/kWt

Bottom Line: Reduced LCOE

- Low maintenance
- Competitive capital cost

Brayton's Solution



Torque Isolation

Avoid imparting strain to receiver tube

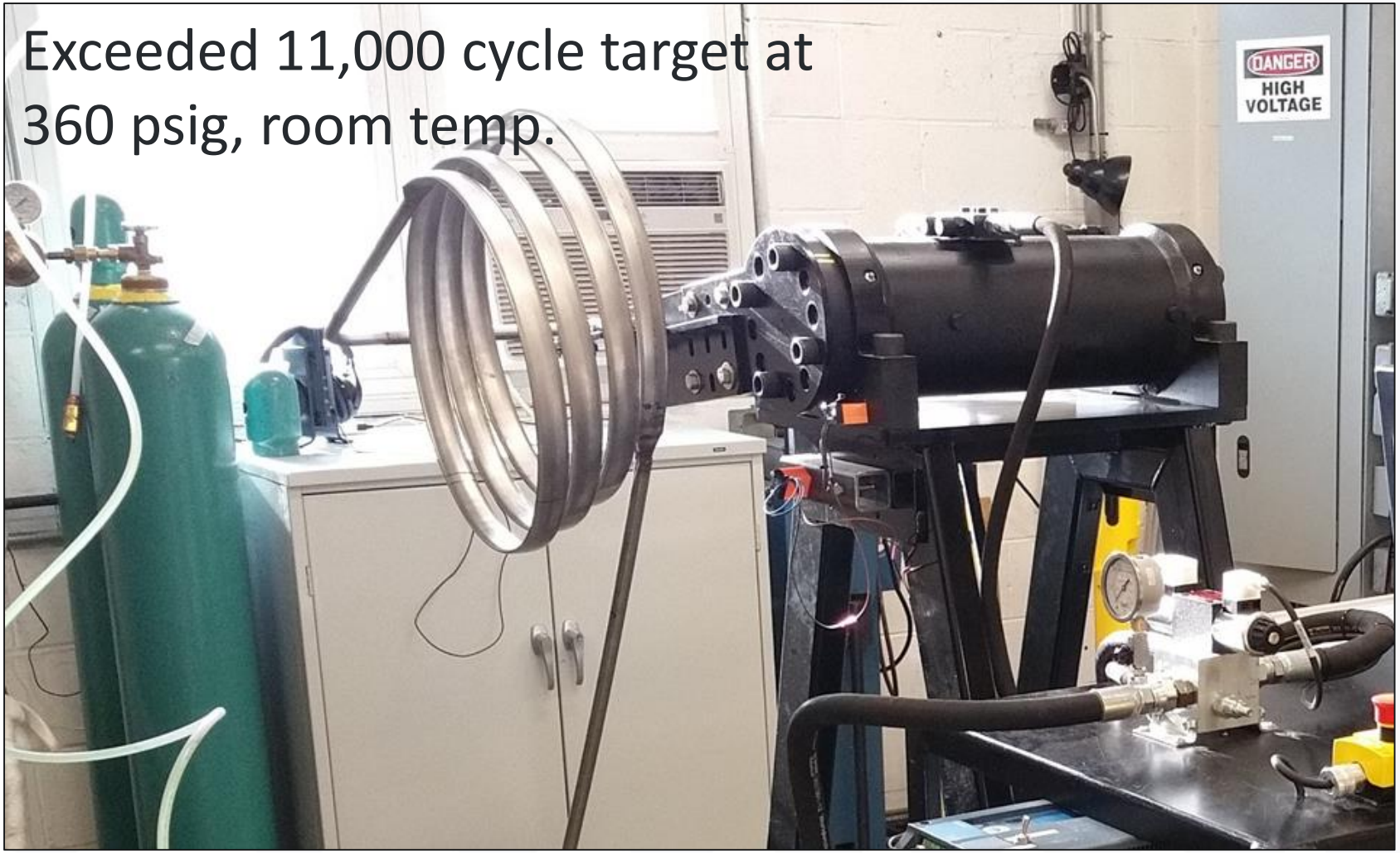
Support and Stabilization System

Supported for gravity, wind, and seismic loading

Freeze Protection and Recovery

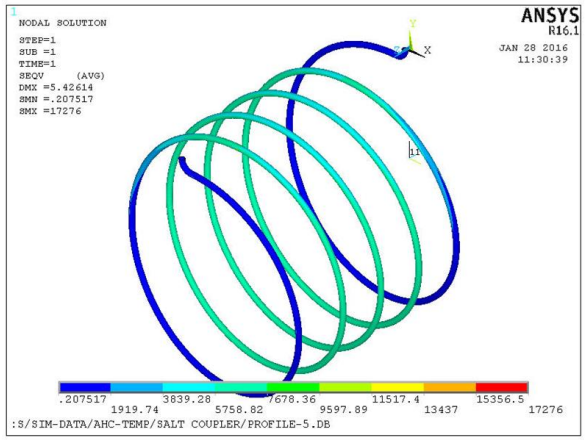
Adopts standard plant pipe insulation and heating system

Phase 1 - First Generation Testing



Activities and Accomplishments - Phase 2

- **Analysis and Optimization**
  - FEA & numerical analysis
  - Support from Sperko Engineering (Walter Sperko, PE) (*code compliance)*
- **Design** - Conceptual system 3D models.
  - Support from SkyFuel and Abengoa
  - Patent pending on gravity support
- **Cost Modeling** - Comprehensive cost estimation tool using commodity pricing from trusted vendors
- **Testing** – Second Generation test program ongoing
- **Commercialization Plan**



Path to Market

Criteria	Description
Code	Design configuration meets *ASME Power Piping Code B31.1*
Intellectual Property	Patents pending on support and stabilization
Detailed Design	Detailed models, drawing package, final cost
Field Testing and Validation at Client Site	Trough (test loop) integration with flowing molten salt, 2017 Q1-2
Manufacturing Development	Validate process and supply chain
Industry Acceptance	Maintain close partnerships with end-users
Sales	Options for licensing technology or manufacturing

Thank you!

PROJECT NAME	Flexible Rotary Pipe Couplers for Molten Salt
FUNDING OPPORTUNITY	DE-FOA-0001258 SBIR/STTR Phase II
PRINCIPAL INVESTIGATOR	William Caruso
LEAD ORGANIZATION	Brayton Energy, LLC
PROJECT DURATION	24 months, Sep. ‘15 - Sep. ‘17
PROJECT BUDGET	$1,491,530